EFFECT OF VARIOUS SUPPLEMENTATION STRATEGIES ON PERFORMANCE OF GOATS CONSUMING LOW QUALITY FORAGE

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CHAPTER I

INTRODUCTION

The research reported in this thesis concerns goats under conditions of low nutritional status. Studies of this nature are of special importance in developing countries in which the quality and quantity of feed resources are often limited. In order for goat producers to know how to most economically provide optional nutritional management with fluctuating feed quality and supply and limited labor, greater knowledge of performance during and after periods of a low nutritional plane is required. Thus, two experiments were conducted, each shedding light onto a different aspect of supplementation.

The first experiment is titled "Effects of Frequency of Supplementation with Soybean Meal on Performance of Angora Does Consuming Low-Quality Forage in Late Gestation and Early Lactation."

There are reports suggesting that ewes and beef cows supplemented as infrequently as once weekly are able to maintain performance levels similar to those supplemented daily, irrespective of stage of production (Beaty et al., 1994; Huston et al., 1999a). Whether Angora does are able to respond similarly to infrequent supplementation during and after gestation is unknown, in part because of their high nutrient requirements for fiber growth. The objective of the study was therefore to examine the effects of no supplementation and supplementation of Angora does with soybean meal every 1, 4, or 8 days, during

periods of high nutrient demands for fetal development and lactation. Measures included feed intake, BW, mohair fiber growth, and other physiological variables. These findings should identify the lowest frequency of supplementation that allows acceptable levels of production.

The second experiment is titled "Effects of Length of Nutrient Restriction and Level of Realimentation on Growth of Yearling Spanish and Boer x Spanish Doelings." Treatments were designed to simulate changes in nutritional conditions between periods of high and low rainfall. Changes in nutritional plane may lead to compensatory growth. Whether goats differing in mature size and growth potential would elicit different responses was examined by comparing indigenous Spanish doelings with Boer x Spanish crossbred goats, of greater mature size and growth potential.

Compensatory growth is defined as a physiological response whereby an organism accelerates its growth after a period of restricted development (usually due to restricted feed intake) in order to reach a weight achieved by animals that have not undergone feed restriction (Hornick et al., 2000). Means by which animals subsequently compensate for slow growth with feed restriction include increased feed intake and(or) improved feed efficiency (Hornick et al., 2000). A greater understanding of how length of feed restriction and re-feeding level interact should lead to improved nutritional management of meat goats for desired levels of performance but with minimal feed inputs.

CHAPTER II

REVIEW OF LITERATURE

Frequency of Supplementation of Ruminants Fed Low-Quality Roughages

There has been a considerable amount of research on the effects of frequency of supplementation on performance by cattle and sheep, but there has not been similar experimentation with goats. Therefore, the literature reviewed for this study primarily concerns other ruminant species.

Animal Performance

Evidence has accumulated since the early 1960's indicating that relative to daily supplementation, ruminant performance is unaffected by infrequent protein supplementation, such as one, two, or three times weekly (Melton et al., 1960, Melton and Riggs, 1964; McIlvain and Scoop, 1962). More recent studies (Huston et al., 1999a and b; Farmer et al., 2001) have shown similar results; however, there is evidence of interaction between breeding season and supplement type and(or) protein concentration (Wallace, 1988; Beaty et al., 1994; Huston et al., 1999a).

Supplement Type and(or) Protein Concentration. A supplement of cottonseed meal (CSM) providing approximately 25% of the CP requirement (NRC, 1985) of ewes during late gestation (NRC, 1985) increased BW regardless of supplementation frequency, i.e., 1-, 2-, (4-) or 7-d intervals, which was observed for both fall and winter-lambing ewes (Huston et al., 1999a). Conversely, Huston et al. (1999a) noted significant effects of supplementation frequency with a supplement that was low in CP concentration (20% CP) (65:35 mixture of sorghum grain andcottonseed meal) and was fed at 105 (LOW) or 227 g/d (HIGH). The LOW supplement supplied one-half the protein and similar energy, and the HIGH supplement supplied similar protein with twice the digestible energy relative to CSM. It was found that with LOW and HIGH, BW gain of fall-lambing ewes was greater for supplementation daily vs once or three times weekly. However, BW gain was similar among the winter-lambing ewes.

Another example of interaction between supplementation frequency and supplement type is an earlier study by Wallace (1988). Cottonseed cake and grain cubes were fed to pregnant yearling heifers grazing dormant rangeland forage. There was no difference in BW change between supplementation frequencies (i.e., once and three times weekly) when cottonseed cake was fed. Supplementation with grain cubes, however, resulted in less BW loss for daily supplementation compared with supplementation twice weekly. Influences of supplementation frequency on reproductive performance also varied with supplement type. Early conception by heifers fed CSM twice weekly (100%) was greater than for those fed grain daily (81%) or twice weekly (58%).

Wallace (1988) further investigated effects of cattle breed (Angus x Hereford vs Simmental x [Angus x Hereford] heifers) on responses to supplementation frequency and supplement type. Angus x Hereford heifers supplemented twice weekly with CSM gained 2.3 times more BW than heifers given grain cubes daily. Using the same comparison, Simmental x [Angus x Hereford] heifers exhibited BW gain eight times greater for twice-weekly supplementation with cottonseed cake compared with daily supplementation of grain cubes. Based on these findings, Wallace (1988) concluded that supplements high in CP may be fed less frequently than grain-based supplements, which may necessitate daily offering.

Although reports of Huston et al. (1999a) and Wallace (1988) indicate less potential for infrequent supplementation with high-starch concentrate vs high-CP feedstuffs, findings of Beaty at al. (1994) are somewhat different. Beaty et al. (1994) offered supplements of increasing CP concentration (12, 20, 30, and 39% CP) or high in grain (74% corn or sorghum) to pregnant beef cows that were fed either daily or three times weekly. There was no interaction between frequency of supplementation and CP concentration or grain type. Regardless of protein concentration in the supplement, cows supplemented three times weekly lost more body condition and weight through calving than cows supplemented daily. Conversely, Kartcher and Adams (1982) and Wallace (1988) reported a reduction in performance when supplements containing relatively low concentrations of CP (< 10%) were fed infrequently. Beaty et al. (1994) discussed these contradictions and attributed the lack of interaction between

supplementation frequency and CP concentration in their study to the source of grain used in the protein supplement. Sorghum grain used by Beaty et al. (1994), compared with corn employed by Kartcher and Adams (1982) and Wallace (1988), has slower and less extensive ruminal starch digestion (Theurer, 1986), which might explain differences in observed responses to infrequent supplementation. Both Wallace (1988) and Kartcher and Adams (1982) attributed lower performance levels among infrequently supplemented animals to the detrimental effects that feeding large quantities of readily fermentable substrate such as corn (0.6% BW, Kartcher and Adams, 1982; 1.28% BW, Wallace, 1988) have on ruminal function. However, when comparing the 74% sorghum and corn based supplements, Beaty et al. (1994) found no difference in performance between daily and three times weekly supplemented cows.

Huston et al. (1999b) found that pregnant adult cows (Brangus or Hereford x Brangus, 3-10 years old) responded similarly when fed CSM daily or three times or once weekly. There were, however, differences between individually fed cows (using Calan gates) and those managed as a group. For individually fed cows there were no differences in BW change or condition score between daily and weekly supplementation. Conversely, group-fed cows supplemented daily experienced lower BW and condition losses than those supplemented less frequently. Irrespective of differences in response between individually and group-fed cows, Huston et al. (1999b) concluded that the findings generally supported the premise that feeding as infrequently as once weekly was acceptable.

In contrast to findings highlighted earlier in which there was no difference among various supplementation frequencies, Farmer et al. (2001) found a linear increase in cumulative BW among spring calving Hereford x Angus cows as frequency of supplementation with a 43% CP concentrate increased, with supplementation 2, 3, 5, or 7 d/week. There was approximately a 0.03 kg/d decrease in BW as supplementation frequency decreased (BW change, kg/d = -0.86 + 0.028x; where x = number of days of supplementation). A similar linear relationship between frequency of supplementation and change in body condition was reported. Based on these findings, Farmer et al. (2001) suggested that caution should be exercised when generalizing about the efficiency of infrequent supplementation. As an example, Huston et al. (1999a) reported that while daily supplementation resulted in performance by fall lambing ewes similar to that with supplementation three times per week, once weekly supplementation was less effective.

With regard to offspring performance, most studies have reported no effect of frequency of supplementation (Morcombe et al., 1988: birth weight; Beaty et al., 1994: calf performance; Farmer et al., 2001: growth rate of lambs).

To examine whether the response to supplementation frequency is similar between pregnant and non-pregnant females, the study by Tovar-Luna et al. (1995) can be compared with those of Huston et al. (1999a), Wallace (1988), and Beaty et al. (1994). Tovar-Luna et al. (1995) reported that non-pregnant yearling heifers grazing native range responded similarly in ADG to supplementation every day or every other day, with a 45% CP supplement of which 46% was

undegradable intake protein. The similarity between this finding and the other reports referred to suggests that non-pregnant females respond to infrequent supplementation as pregnant females do.

Based on the studies discussed, it is evident that the efficacy of infrequent supplementation depends on supplement composition, e.g., protein and starch contents. Grain-based supplements seem to necessitate more frequent supplementation than high protein concentrates. Conversely, comparing supplements of increasing CP concentration and different grain types (corn vs sorghum), Beaty et al. (1994) did not observe interactions between supplementation frequency and CP concentration or grain type. This study reported that less frequently supplemented beef cows lost more BW irrespective of the CP concentration and grain type of the supplement fed compared with daily supplementation. High protein supplements generally have resulted in similar BW change among supplementation frequencies ranging between daily and twice weekly (Kartcher and Adams, 1982; Wallace, 1988; Huston et al., 1999a and b). Findings were similar with non-pregnant heifers as well (Tovar-Luna et al., 1995). However results of Farmer et al. (2001) indicate that although small in magnitude, increasing frequency of supplementation results in improved BW. The magnitude of impact of infrequent supplementation on performance should therefore be weighed against the advantage of decreased labor expenses to determine desirability of the practice.

Feed Intake. Dry matter, nitrogen (N), and ME intakes typically increase with protein supplementation of low quality forage (< 7.5% CP) (Collins and Pritchard, 1992; Beaty et al., 1994; Krehbiel et al., 1998), and respond quadratically to increasing protein concentration (DelCurto et al., 1990; Beaty et al., 1994). Infrequent supplementation of low quality forage (< 7.5% CP) with high protein supplements, ranging from one to three days weekly, has not significantly affected total feed (forage + supplement) or forage intake compared with daily supplementation (Calhoun et al., 1988; Hunt et al., 1989; Huston et al., 1999b). This suggests partial to complete substitution of supplement for the basal dietary forage (Huston et al., 1999b).

Contrary to the above, there are reports suggesting that reducing supplementation frequency decreases forage intake (Collins and Pritchard, 1992; Beaty et al., 1994; Krehbiel et al., 1998; Huston et al., 1999; Farmer et al., 2001). There may, however, be an interaction between supplementation frequency and time or day within the supplementation interval. For example, Krehbiel et al. (1998) reported that forage intake by ewes supplemented every 3 days had lower forage intake on the day of supplementation, which was presumably due to the large amount of supplement offered, compared with those supplemented daily. Forage intake 1 and 2 days following supplementation was considerably greater than on the day of supplementation. Depending on when intake measurements are taken, effects on feed intake may therefore vary.

Differences in reports on effects of supplementation frequency on intake may also be explained by changes in feeding behavior (Krehbiel et al., 1998).

Huston et al. (1999b) reported that grazing cows supplemented daily vs less frequently displayed more aggressive feeding behavior. The response to calling was slower for less frequently supplemented animals, and those first at the feed bunks fed freely and left with feed still remaining in the bunks. This allowed slower responding animals to feed without competition or disturbance from the more dominant ones, and resulted in more similar supplement consumption among less frequently supplemented animals vs daily supplemented.

Urea and Ammonia Concentrations

An understanding of physiological mechanisms through which less frequently supplemented animals in many instances maintain levels of performance similar to those supplemented daily is less established than effects on performance. Blood urea-nitrogen (BUN) concentration, an indicator of efficiency of protein utilization (Preston et al., 1965), interacts with supplementation frequency (Beaty et al., 1994). Patterns of change in BUN concentration during days relative to the day of supplementation differ between daily and less frequently supplemented animals (Beaty et al., 1994; Huston et al., 1999a and b). In this regard, Huston et al. (1999a) noted that pregnant ewes supplemented once weekly had elevated BUN levels 2 days following supplementation, compared with ewes supplemented daily. However, non-pregnant yearling heifers supplemented every other day had similar BUN levels the day after supplementation compared with heifers supplemented daily (Tovar-

Luna et al., 1995). Likewise, infrequently supplemented pregnant cows had lower BUN levels 1 day after supplementation vs the day of supplementation (Huston et al., 1999b). Overall, infrequently supplemented animals appear to maintain similar or higher BUN levels within 2 days following supplementation, compared with animals supplemented daily (Huston et al., 1999a; Beaty et al., 1994; Farmer et al., 2001). Consequently, this should facilitate urea recycling to the rumen for microbial use during days of low CP intake (Krehbiel et al., 1998).

Ruminants recycle substantial amounts of N by urea transfer across the rumen or via saliva. Rumen wall adherent bacteria hydrolyze urea to ammonia that can be used by microbes within the rumen lumen (Krehbiel et al., 1998). A high blood urea concentration promotes transfer into the rumen, although it is generally thought that the gradient is more important than the urea concentration in the blood (Preston et al., 1965, Hammond, 1983). In this regard BUN concentration patterns of change in less frequently supplemented animals, compared with those of daily supplemented ones, are associated with similar patterns of ruminal ammonia nitrogen (NH_3-N) (Collins and Pritchard, 1992; Beaty et al., 1994; Huston et al., 1999a). Patterns of change in BUN concentration as day of the supplementation interval advance mirror those of ruminal NH_3-N (Krehbiel et al., 1998). In accordance, Beaty et al. (1994) found that within the first few days following supplementation, less frequently supplemented animals have higher ruminal NH_3-N concentrations than more frequently supplemented animals. The decline in ruminal NH_3-N concentration, a

few days before the next supplementation, is slow, reaching levels lower than animals supplemented daily.

Supplementation frequency not only affects daily BUN and ruminal NH_3-N concentrations (Beaty et al., 1994; Huston et al 1999a; Huston et al., 1999b), but also impacts diurnal variation (Collins and Pritchard, 1992; Beaty et al., 1994; Tovar-Lunar et al., 1995; Farmer et al., 2001). Within a few hours following supplementation, less frequently supplemented animals have greater peaks in ruminal NH_3-N and BUN concentration than those supplemented daily (Beaty et al., 1994; Tovar-Lunar et al., 1995; Farmer et al., 2001), which may simply be because of greater amounts of supplement fed to less frequently supplemented animals on days of supplementation. Peaks in ruminal NH_3-N and BUN with infrequent supplementation are delayed and declines more slowly compared with daily supplementation (Beaty et al., 1994; Farmer et al., 2001).

Crude protein concentration and type of supplement influence temporal patterns of change in BUN and ruminal NH_3-N concentrations (Collins and Pritchard, 1992; Beaty et al., 1994). Levels for animals consuming supplements higher in CP and(or) rich in ruminally degradable CP peak later and higher and have a slower rate of decline than with supplements low in CP and(or) ruminally degradable CP (Collins and Pritchard, 1992; Beaty et al., 1994; Huston et al., 1999b).

Rumen Digestibility and pH

There are conflicting results concerning how DM digestibility is influenced by supplementation frequency. For example, Coleman and Wyatt (1982) reported no effect of frequency of CSM supplementation on DM digestibility. However, Beaty et al. (1994) observed greater DM and NDF digestibilities with supplementation daily vs every third day.

Ruminal pH has not consistently differed among supplementation frequencies. Beaty et al. (1994) reported that on days of supplementation, less frequently supplemented animals had lower pH than animals supplemented daily, although in another study pH was unaffected by supplementation frequency (Collins and Pritchard, 1992).

Nitrogen Utilization

As noted earlier, N recycling is the most plausible explanation for maintained performance among infrequently supplemented animals (Nolan and Leng, 1972; Beaty et al., 1994; Krehbiel et al., 1998; Huston et al., 1999a and b; Farmer et al., 2001). Nitrogen is continuously recycled to the rumen from the bloodstream and saliva for re-utilization and is seen as a conservation mechanism allowing ruminant animals to survive on diets low in N (Owens and Goetsch, 1988). Most N is recycled to the rumen via plasma urea, and depending on the level of protein or N intake, this route accounts for 23-92% of the N

recycled to the digestive tract (Owens and Goetsch, 1988). The concentration gradient of urea between the blood and the rumen lumen, which influences the degree of diffusion, is primarily governed by activity of urease produced by bacteria adhering to the rumen wall (Krehbiel et al., 1998). Urease activity is in turn regulated by ruminal ammonia concentration, with low levels causing high activity (Owens and Goetsch, 1988). Thus, diets low in total and(or) ruminal degradable CP promote high recycling through low ruminal ammonia concentration, whereas diets high in total and(or) ruminal degradable CP tend to decrease N recycling via the accompanying high blood urea concentration.

Supplementation may cause an increase in arterial concentration of α-amino acid nitrogen (AAN) (Krehbiel et al., 1998). Krehbiel et al. (1998) further noted a supplementation frequency x time (day relative to day of supplementation) interaction. It was found that when ewes were supplemented every third day with SBM, AAN release from the portal drained viscera (PDV) on the day after supplementation (d 1) was greater compared with the second day after supplementation (d 2) and lowest on the day of supplementation (d 0). Animals supplemented daily had a PDV release of AAN similar to non-supplemented ewes.

As expected, SBM supplementation of ewes consuming low quality forage increased net PDV flux of NH_3-N, but there was no difference among different frequencies in overall means (Krehbiel et al., 1998). There was, however, an interaction between supplementation frequency and time relative to day of supplementation. In ewes supplemented every third day, the portal-arterial NH_3-N

concentration difference was higher on d 1 followed by that at 2 d after supplementation and lowest on d 0. These differences are similar to those previously described for net PDV release of AAN. The temporal patterns of change in PDV release of AAN and NH_3-N on d 0, 1, and 2 after supplementation, as noted by Krehbiel et al. (1998), seem to follow patterns similar to BUN concentration noted in a number of studies (Collins and Pritchard, 1992; Beaty et al., 1994; Huston et al., 1999a; Farmer et al., 2001).

Krehbiel et al. (1998) reported that the sum of AAN and ammonia N uptake by the liver on d 1 after supplementation ranged from 25.5 mmol/h for the control, 83.0 mmol/h for ewes supplemented daily, and 116.8 mmol/h for ewes fed SBM every third day. These findings suggest that less frequently supplemented animals are better able to conserve N by increasing liver uptake of AAN and ammonia N on d 1 and 2 after supplementation.

On d 1 after supplementation, both daily and every third day supplemented ewes displayed greater N uptake by the liver than urea-N synthesized, which accounted for 56-100% of liver AAN and ammonia N removal (Krehbiel et al., 1998). Differences in urea-N synthesized on d 1 after supplementation was 63.5 and 91.5 mmol/h for daily and every third day supplementation, respectively.

Krehbiel et al. (1998) found that of the net transfer of urea-N to the PDV in ewes supplemented daily or every third day, 20-40% was accounted for by hepatic release. Values were greater (28–52%) for the non-supplemented controls and lower for ewes supplemented daily (12.6–23%). On the day of

supplementation, net PDV uptake of urea was only 12.3% of N intake. However, on the second day after supplementation 74% of PDV urea uptake could be attributed to N intake. This indicates that N recycling varies with time in infrequently supplemented animals, increasing as day after supplementation advances. This pattern appears similar to increases in ruminal ammonia N and BUN levels on the first and second day after supplementation, as reported by Huston et al. (1999a) and Beaty et al. (1994).

The previously discussed interaction between supplement type and supplementation frequency affects urinary N excretion as well. For example, Collins and Pritchard (1992) reported that urinary N excretion tended to be greater 1 d after supplementation with SBM vs CSM, possibly because of a greater concentration of ruminally degradable CP in SBM. With SBM supplementation every other day, urinary N excretion was lower on d 1 after supplementation vs d 0 (day of supplementation) (Coleman et al., 1982; Collins and Pritchard, 1992). Likewise, mean urinary N excretion was less with supplementation every other day vs daily. These findings are in accordance with results of Krehbiel et al. (1998) who reported greater PDV uptake of urea-N by ewes on d 2 after supplementation with a 3-d interval.

Metabolites and Hormones

Studies vary in reported effects of supplementation frequency on ruminal VFA. Collins and Pritchard (1992) reported that there was no effect on mean

ruminal fluid concentration of VFA. This is in agreement with the earlier discussion of the adequacy of ruminal N recycling among infrequently supplemented animals, thus maintaining ruminal NH_3-N concentrations above levels that can limit microbial growth and digestion (Satter and Slyter, 1974). Collins and Pritchard (1992) also reported no effect of supplementation frequency on proportions of the major VFA: acetate:propionate:butyrate of 74:18:7 and 74:18:7 for SBM supplemented daily and every other day, respectively. However, Farmer et al. (2001) reported greater total VFA concentrations for steers supplemented daily vs 3, 5, or 7 d/wk on days when only daily supplemented steers were fed. An inverse relationship between total VFA concentration and supplementation frequency was evident on the day when all groups were supplemented, which appeared to be largely due to the greater quantities of supplement fed to infrequently supplemented groups.

Effects of frequency of supplementation on blood hormone concentrations have not been extensively studied. Tovar-Luna et al. (1995) fed yearling heifers a roughage diet supplemented with concentrate containing 45% CP of which 46% was undegradable intake protein. Supplementation was daily or every other day. There were no differences in serum insulin or growth hormone concentrations. This is in accordance with the adequacy of N recycling with infrequent supplementation to maintain ammonia concentrations that allow normal microbial function for similar energy and nutrient absorption compared with daily supplementation (Petersen et al., 1992; Beaty et al., 1994; Krehbiel et al., 1998).

Amino Acid Metabolism

Ruminants like all mammals require an exogenous supply of essential AA; however, because ruminal fermentation leads to the production of microbial protein they are often not perceived as having essential amino acid requirements (Merchen and Titgemeyer, 1992). During periods of high protein requirements, such as late gestation or early lactation, microbial protein production may not be sufficient to meet protein demands, and an exogenous supply of amino acids becomes essential. Furthermore, providing an array of amino acids for absorption in the small intestines that matches tissue needs is especially difficult in ruminants because of ruminal protein degradation. Nitrogen metabolism in ruminants is thus often considered to be inefficient (Lobley, 1992).

As noted earlier, performance of less frequently supplemented ruminants has generally not differed from those supplemented daily. However, there has been little research with highly productive ruminants such as mohair producing Angoras, as is also true for production states with high amino acid requirements such as late gestation and early lactation. Furthermore, previous studies have not investigated blood amino acid concentrations with animals supplemented at different frequencies.

Under conditions where microbial protein is the primary protein source in growing ruminants, methionine, lysine, and threonine have been found to be first, second, and third limiting, respectively, with arginine and histidine also potentially limiting nitrogen retention (Richardson and Hatfield, 1978; Storm and Ørskov,

1983; Merchen and Titgemeyer, 1992). The degree of protein degradation and the quality of protein escaping degradation in the rumen influence which amino acids are limiting. With a diet high in degradable protein containing 80% barley, methionine was first limiting (Fenderson and Bergman, 1975). However, it is difficult to identify a single amino aicds as being first limiting, since infusion of methionine in combination with other essential amino acids has improved performance over that of animals infused with methionine only (Merchen and Titgemeyer, 1992).

Feed intake is directly related to net portal fluxes of most amino acids (Nozière et al., 2000). Because feed intake has typically not been affected by infrequent supplementation, e.g., once every 3 d, it could be expected that AA flux will not be influenced by infrequent supplementation.

Mohair Production

An important consideration for wool producing sheep and mohair producing Angora goats is the potential impact of frequency of supplementation on fiber growth characteristics. Morcombe et al. (1988) offered a supplement high in lupin grain to pregnant ewes at 3, 4, 7, 14, or 21 d intervals, while grazing wheat stubble. Wool growth, mean fiber diameter, clean yield, and mean staple strength were similar among treatments. Wool growth was affected by production state, with mean length of wool grown per day lowest before and immediately after lambing (0.197 – 0.201 mm/d) and higher during lactation (0.206 – 0.214

mm/d), although the weakest point of the fiber was grown during lactation (Morcombe et al., 1988).

Calhoun et al. (1988) examined the effect of supplementation frequency, using CSM (48.2% CP), on mohair production and fleece characteristics. Supplement was given every 1, 2, 3, 4, or 5 days. Average daily gain, voluntary hay intake, fleece production, fiber diameter, and number of medullated (med and kemp) fibers were similar among frequencies.

Fiber production responds positively to increased protein intake (Reis et al., 1990). Likewise, there is a linear relationship between total feed intake and fiber growth rate (Russel, 1992; Hynd, 2000), and since there has often been no difference in feed intake among supplementation frequencies, similar feed intake may explain similar fiber growth and characteristics in the studies of Morcombe et al. (1988) and Calhoun et al. (1988).

Another possible explanation for similar fiber growth characteristics between daily and less frequently supplemented animals may be genetically based. Adams et al. (2000) suggested that breeds selected for superior fiber growth are able to maintain a more consistent fractional synthesis rate of protein in skin, irrespective of feeding level, compared with unselected animals. Thus, animals selected for high fiber growth may exhibit less variation in this trait regardless of nutritional plane compared with genetically inferior animals. This is perhaps because of nutrient partitioning mechanisms enabling control of the effects of nutrition on fiber growth.

Compensatory Growth of Ruminants

Compensatory growth may be defined as a physiological response whereby an organism accelerates its growth after a period of restricted development (usually due to restricted feed intake), in order to reach a weight achieved by animals that have not undergone feed restriction (Hornick et al., 2000). Mechanisms by which animals are able to compensate growth lost during feed restriction include improved feed intake and feed efficiency during periods of realimentation (Hornick et al., 2000).

The degree to which animals exhibit compensatory growth is influenced by factors such as severity or level of feed restriction and realimentation, the nutritional condition most limiting to growth (e.g., protein vs energy), lengths of feed restriction and realimentation, sex, and age of the animal. To best discuss compensatory growth, the discussion will be divided into two parts, feed restriction (the period preceding realimentation, during which growth in comparison with non-supplemented controls is restricted) and realimentation (the period immediately following restriction, in which animals compensate for previously limited growth).

Feed Restriction

Type and(or) Severity of Feed Restriction. When basic nutrient requirements of ruminants are not met, depending on the severity and(or) type

and length of the restriction, tissue reserves are utilized with consequential losses in BW and body condition that could ultimately lead to death (Ørskov, 1982; Ørskov and Ryle, 1990). The influence of decreasing levels of feed intake was examined in a study by Gómez-Pastén et al. (1999) in which feed intake of adult female non-pregnant, crossbred Nubian goats was restricted for 36 wk to 100, 80, or 60% of the observed average daily consumption of a 50% lucerne hay and 50% sorghum stover diet. There was a significant decrease in BW and carcass yield, and by design decreasing levels of intake, although 60 and 80% treatments showed no difference in BW loss. Similar findings were reported by Ferrell et al. (1986). It was furthermore reported that hepatic protein and muscle DM and ether extract decreased with decreasing levels of intake, which indicate increased utilization of body protein and fat reserves. These results are in agreement with similar studies and reviews (Bergman, 1975; Ørskov and Ryle, 1990; Hornick et al., 2000) which reported that severely restricted ruminants rely on body reserves to meet nutrient requirements.

In a study by Sahlu et al. (1999a) the effects of decreasing levels of feed intake (51, 65, 83, and 100% of ad libitum intake of a 14.7% CP, 70% concentrate diet for 40 d [severe restriction, moderate restriction, low restriction, and ad libitum intake, respectively]) did not affect BW change in the last 20 d of restriction, although loss of BW increased linearly with increasing levels of restriction in the first 20 d of restriction. In general, digestibilities of DM, energy, and N were lower in ad libitum vs restricted treatments, presumably due to greater feed intake.

The above two studies indicated that restricted feed intake has an immediate effect on ADG, with decreases in BW peaking within the first few days of restriction. Depending on the severity of the restriction of intake and metabolism of the animal, an equilibrium could be reached within days of restriction. There are subsequent increases in fat mobilization with increasing levels of restriction, and possibly an additional decrease in body protein.

For comparison with restricted feed intake, the influence of length of feed restriction on Belgian Blue bulls (Hornick et al., 1998) is discussed. After 115, 239, and 411 d (G2, G3, and G4, respectively) of feed restriction for an ADG of 0.5 kg/d, with ad libitum consumption of a diet limiting in both protein and energy, BW ranked G4 > G3 > G2 (486, 435, and 368 kg, respectively). Actual ADG was close to 0.5 kg/d during the restriction period, although it was slightly higher in G2 and lower in G4. Daily feed intake was close to 6 kg/d among the three groups, although higher in G4. Feed consumed per unit of ADG was however high and increased with increasing length of feed restriction (10.2, 11.1, and 14.4 kg/kg for G2, G3, and G4, respectively).

What is evident when comparing the above reported studies (Hornick et al., 1998; Gómez-Pastén et al., 1999; Sahlu et al., 1999a) is that animal performance during restricted periods may vary with type and severity of restriction. When feed intake is restricted as in the studies of Gómez-Pastén et al. (1999) and Sahlu et al. (1999a), there are proportional decreases in BW and carcass yield. However, in the case with ad libitum intake of a nutrient restricted diet at a predetermined ADG, DM intake would tend to increase to compensate

for poor feed quality. The different effects of restriction treatments on intake could lead to differences in visceral organ energy use, PDV weight, and consequently BW gain, and feed efficiency (Ortiques and Dorea, 1995; Goetsch, 1998). Variation in PDV weight with DE intake may contribute to changes in energy maintenance requirements and in turn differences in animal performance during subsequent realimentation periods (Ortiques and Dorea, 1995; Sainz et al., 1995; Goetsch, 1998; Nozière et al., 2000).

It is possible that animals exposed to levels of low to moderate feed restriction are capable of maintaining BW by adjusting basal metabolic rate, energy requirements, and nutrient flux (Nozière et al., 2000). This ability may be further influenced by growth potential and age or maturity (Steen, 1986; Goetsch, 1999; Hornick et al., 2000).

Nozière et al. (2000) investigated the effects of moderate levels of feed restriction on PDV metabolism with the following treatments: 143 (H), 88 (M), and 51% (L) of maintenance energy requirements of adult ewes. The sum of net portal energy flux increased linearly as ME intake rose, with 51% of the ME intake recovered in portal blood with the three levels of intake. The loss in ME (49% intake) corresponded mainly to heat of fermentation and heat production by PDV tissues. In agreement, Lindsay (1993) reported that 52-59% of ME intake was released in the portal vein and that heat production by PDV tissues as a percentage of ME intake increased in response to underfeeding (Ortiques and Durand, 1995). Nozière et al. (2000) noted that underfeeding did not modify the contribution of VFA to ME absorbed, but the contribution of amino acids

decreased from 16% for H and M to 1% for L. The contribution of 3-hydroxyutyrate and lactate increased from 10 to 15% and from 4 to 10% for H and L intake levels, respectively. It was thus concluded that there was no quantitative adaptation to spare energy in the PDV, in terms of percentage intake, but the pattern of absorption of energetic nutrients was modified.

Body Composition. In addition to the effect of feed restriction on BW, effects on body composition are evident. During normal growth muscle initially exhibits the highest growth rate followed by fat tissue (Hornick et al., 2000). With decreased growth rates there is a coordinated decrease of tissue turnover with some tissues reacting more than others (viscera > adipose tissue > muscle), resulting in an overall decrease in visceral organ mass (Carstens et al., 1991; Wester et al., 1995; Hornick et al., 2000). Because fat deposition is more affected than protein deposition, during restriction the body consequently becomes leaner (Hornick et al., 2000).

Severe feed restriction is characterized by a sharp decrease in protein synthesis relative to degradation, indicating that mechanisms of synthesis are more susceptible to feed restriction than degradation (Hornick et al., 2000). Initial weight loss results from an early mobilization of a very labile protein compartment (Paquay et al., 1972) that lasts for a few days until a new equilibrium is reached, possibly caused by a decrease in basal metabolism. Depending on the nutritional status of the animal, metabolic activity, and the severity of feed restriction, fat mobilization increases, whereas protein is

conserved as long as possible. Eventually as the animal becomes leaner, the muscle becomes the main source of energy, causing greater protein than fat losses (Foot and Tulloh, 1977).

Type of feed restriction and(or) diet quality and quantity may affect body composition at the end of feed restriction and thus possibly after realimentation. In this regard, restricted energy consumption by the gastrointestinal tract and liver may be directly related to tissue mass (Burrin et al., 1990; Johnson et al., 1990). As an example, Drouillard et al. (1991) restricted growth of crossbred lambs by use of protein and energy deficient diets. Diets deficient in metabolizable protein (PR) and net energy (ER) were formulated to allow for maintenance of BW at ad libitum intake. At the end of a 42 d restriction period, PR lambs lost protein (16 g/d), fat (15 g/d), and water (78 g/d). Conversely, ER lambs experienced no change in protein mass but lost fat (20 g/d) and water (42 g/d). Thus, the ER animals provided with sufficient dietary protein maintained body protein and mobilized body fat for energy to maintain protein mass. Conversely, PR lambs were forced to mobilize protein to satisfy maintenance or endogenous losses, and to provide specific amino acids essential for vital functions. These findings are in agreement with a later review by Chowdhury and Ørskov (1997), in which it is reported that adequate dietary protein with low energy intake by sheep and cattle permitted gain of protein even with a negative energy balance (presumably by oxidizing body fat). Increasing protein supply, even without exogenous energy increased N retention, and at a very high level of protein supply ADG reached 0.8 kg/d.

Visceral Organ Mass. Part of the decrease in empty body weight with restricted nutritional planes can be attributed to decreased visceral organ mass. Absolute weights of the, liver, stomach complex, and intestines are dramatically reduced by feed restriction (Ferrell et al., 1986; Richmond et al., 1988; Burrin et al., 1990; Drouillard et al., 1991). Likewise, Kamalzadeh et al. (1998) observed that proportions of visceral organs, feet, head, and blood relative to BW decreased during feed restriction, although the rate of decline varied among body components and visceral organs. This in turn may influence maintenance energy requirements, which is demonstrated by findings of Drouillard et al. (1991). Drouillard et al. (1991) noted similar in vitro oxygen consumption per unit mass of liver slices by restricted and unrestricted lambs, suggesting that the decline in energy use by visceral organs during feed restriction is proportional to the change in organ mass.

The decreased proportional weights of body components with high metabolic activity at the end of feed restriction, particularly visceral organs, may influence subsequent ADG during realimentation because of a decreased maintenance energy requirement (Ledger and Sayers, 1977; Ferrell et al., 1986). Organs with higher rates of decline in mass during restriction likewise recover rapidly upon re-feeding. The impact of decreased organ mass after restriction on subsequent ADG during realimentation thus depends on the length of time before normal mass and energy use is achieved (Kamalzadeh et al., 1998). In this regard, Richmond et al. (1988) conducted a study to determine if compensatory gain resulted from lowered maintenance energy requirements due to decreased

visceral organ mass or metabolic rate. Hereford steers averaging 369 kg BW were restricted for 0, 3, 7, or 14 d (50% of previous individual ad libitum consumption) followed by 7, 14, 21, or 28 d of realimentation for the 14 d restricted steers only. During realimentation concentrate intake was increased by 0.9 kg/d until previous ad libitum consumption was reached, with ad libitum consumption thereafter. The largest proportion of liver mass was lost in the early stages of the restricted feeding period and was regained within 7 d of realimentation, followed by an increase in lean tissue deposition without a concurrent increase in vital organ mass. Since liver mass was regained so rapidly during realimentation, it was concluded that compensatory gain influenced by a lowered maintenance energy requirement was not only due to decreased vital organ mass.

It is thought that decreases in visceral organ and gastrointestinal tract (GIT) tissue mass and metabolism may be caused by decreases in DE intake and digestible organic matter intake (DOMI) (Kouakou et al., 1997a; Goetsch, 1998). In another study by Kouakou et al. (1997b), crossbred wethers were used to determine effects of different grass sources and qualities on visceral organ mass after consumption of bermudagrass or orchardgrass at different levels of maturity for 42 or 84 days. It was reported that increasing length of feeding showed no substantial change in GIT energy use by growing ruminants, despite ad libitum consumption of grasses varying in quality. It was further reported that both DOMI and digesta mass influenced GIT tissue mass, and that liver mass was attributed more to changes in GIT tissue mass than DOMI. It was concluded

that physical attributes of digesta resulting from low- to moderate-quality grasses may affect splanchnic tissue mass and energy use. The implication of this study is that restricted energy consumption can change the weight of visceral organs, which has further implications for maintenance energy requirements during feed restricted periods and subsequent realimentation periods.

Grazing Management Systems. Management strategies to improve grazing and subsequent feedlot animal performance often include the manipulation of compensatory growth displayed by previously restricted animals. The phenomenon of compensatory growth is of considerable practical significance to animal production (Park et al., 1987; Drouillard and Kuhl, 1999). Substantial diversity exists among the major forage-producing areas in terms of plant species, annual precipitation, soil fertility, and other environmental conditions. The expression or absence of compensatory growth during the finishing phase appears to be related to the nutritional quality of forages utilized in the grazing period, with higher quality forages tending to yield greater compensatory effects.

Phillips et al. (2001) addressed the influence of forage quality on post-weaning and feedlot performance between yearling spring-born calves, assigned to grazing winter wheat pasture (WW) or dormant native prairie plus a concentrate supplemental (NP). At the end of these winter stocker treatments, lasting for 4 months, calves grazed on cool-season grasses as a single group for 4 months. Thereafter they were placed in a feedlot and fed a high concentrate

diet for 120 days, or until backfat thickness was greater than 10 mm. As expected, ADG in the wither stocker phase was greater for WW than for NP. In the spring, ADG was similar between treatments and 50% greater than in the winter. No compensatory growth was observed among the NP-treated calves during the spring. This suggested that the spring grazing conditions were not conducive to expression of compensatory growth potential for NP, given the mode of development.

In addition to nutritional quality of forages, plane of nutrition during grazing periods also influences live weight gain, and thus subsequent potential for compensatory growth. As an example, the optimum level of performance during the winter is largely determined by the extent in which animals over-wintered on a low plane of nutrition exhibit compensatory growth at pasture (Steen, 1986). Recommendations for live weight gain during winter to optimize compensatory growth when turned out to pasture range from 0.25 to 0.60 kg/d (Drennan, 1975; Baker, 1975; Allen and Kilkenny, 1984). Recommendations may however differ with age or maturity, and thus could differ among breeds. As an example, Drennan and Harte (1979) reported that cattle of 8 to 13 mo of age that have been reared on a low (0.50 kg/d) or moderate plane of nutrition (0.66 kg/d) had a recovery index of 0.39 and 0.71, respectively. A recovery index is often used to quantify the degree to which animals display compensatory growth, estimated as A-B/A, with A being the weight difference between the control and the experimental groups at the end of the period of restriction and B the weight difference between the control and experimental groups at the end of a period of

realimentation. Conversely, Steen (1986) observed that steers on a low plane of nutrition (ADG = 0.4 kg/d) during a winter period displayed a greater degree of compensatory gain when turned out to pasture compared with those that were on a higher plane of nutrition (ADG = 0.7 kg/d). Differences in compensatory response between these two studies (Drennan and Harte, 1979; Steen, 1986) were attributed to differences in breed type in terms of age at maturity, i.e., early maturing vs late maturing (Steen, 1986).

Realimentation

Feed Intake and Feed Efficiency. Compensatory growth typically occurs as a function of increased feed intake and(or) improved efficiency of feed utilization (Drouillard et al., 1999; Yambayamba et al., 1996; Goetsch and Aiken et al., 1999; Sahlu et al., 1999a). In some instances one but not the other occurs, whereas in other cases both are noted. As an example, in trial 2 of Drouillard et al. (1991), during realimentation DM intake by PR and ER lambs was 7 and 19% greater than control lambs. In trial 1, DM intake by PR and ER lambs was similar during the first 2 week of realimentation and tended to be greater than the control lambs from 2 week to 50 kg BW. Empty BW gain for PR and ER was greater than that of unrestricted lambs, although there was no difference between the restriction treatments; hence, efficiency of feed conversion from 2 wk to 50 kg BW was not different between PR and ER and was also similar to that of unrestricted lambs. Efficiency of protein deposition was 6.6 g of protein

retained/gram protein consumed for unrestricted lambs, and averaged 7.5 for PR and ER lambs.

Sahlu et al. (1999a) observed a linear increase in BW gain and efficiency of feed conversion by Angora goats during realimentation as the prior level of feed restriction increased (i.e., no restriction, low, moderate, and severe at 100, 83, 65, and 51% ad libitum intake, respectively). Similar findings were reported by Hornick et al. (1998) when Belgian Blue bulls were subjected to different lengths of restriction, i.e., 115, 239, or 411 d (designated G2, G3, and G4, respectively), and then offered a high concentrate diet with ad libitum consumption in a 1 mo (month) realimentation period. At the end of realimentation, ADG of restricted groups was higher than those of the control. The G2 and G4 groups exhibited the highest compensatory gain and greatest feed intake (11.8, 12.1, 9.7, and 10.7 kg/d for G2, G4, control, and G3, respectively). Feed conversion ratio (feed:gain) was however similar among the four groups, averaging 7.5 kg/kg; final BW was similar for the control, G2, and G3, with the ratio for G4 being the highest. Considering both periods combined, ADG decreased with increasing length of restriction. However, total gain was greatest for G4.

Nature of Feed Restriction. Compensatory gain has in some cases been affected by the nature of nutrient restriction. For example, Goetsch and Aiken (1999) used wethers to determine effects of limited intake of an 80% concentrate diet and ad libitum intake of forage (long stemmed alfalfa hay) on subsequent

performance while consuming a high concentrate diet ad libitum. Treatments were ad libitum intake of an 80% concentrate (AC) diet for 14 wk, restricted intake of concentrate for 8 wk followed by 6 wk ad libitum intake of concentrate (LC), ad libitum intake of forage for 8 wk followed by 6 wk ad libitum intake of concentrate (F), and 6 wk ad libitum intake of forage followed by 2 wk restricted intake of concentrate, then 6 wk ad libitum intake of concentrate (F-LC). Despite similar empty BW and ADG among treatments (F, LC, and F-LC), at the end of feed restriction LC and FC wethers had greater subsequent ADG than F-LC with ad libitum consumption of a concentrate diet during realimentation.

Conversely, there are studies suggesting that diets varying in energy:protein and forage content, but which sustain the same growth rate during restricted periods, may not affect subsequent performance during realimentation (Steen, 1986; Drouillard et al., 1991). In accordance, wethers previously restricted by feeding diets with different levels of cereal grain and protein sources, with ad libitum intake of hay, displayed similar ADG in both the restricted (83 d) and realimentation phases (63 d) when an 80% concentrate diet was consumed ad libitum (Goetsch, 1999). Dry matter and whole body composition were similar after realimentation.

Body Composition. Effects of type of diet on subsequent growth rate during realimentation are likely to be mediated through differences in body composition at the end of a restriction period (Kirby et al., 1983; Steen, 1986; Goetsch, 1999; Goetsch and Aiken, 1999). Drouillard et al. (1991) reported that

the WW treatment at the start of the finishing phase. Carcass analysis showed that at the end of the feedlot phase, hot carcass weight was lower (315 vs 337), longissimus muscle area was smaller (81.8 vs 84.9 cm^2), kidney, pelvic, and heart fat percentage was less (2.26 vs 2.32%), and dressing percentage was lower (61.3 vs 62.2) for NP vs WW calves. Although, fat depth, yield grade, and marbling score were not different. It was therefore concluded that dormant native grass can be used to winter stocker calves in addition to winter wheat pasture, but the ownership of these calves would have to be retained through the feedlot phase to realize any advantage of built-in compensatory gain.

Metabolite and Hormone Status During Feed Restriction and Realimentation.

Animals adapt to feed restriction by metabolic and endocrine alterations (Hornick et al., 2000), which along with a decrease in visceral mass cause a decline in basal metabolism. Blood serum status of metabolites and hormones thus plays an important role during feed restriction (de Boer et al., 1985) and affects growth responses during realimentation.

Glucose and NEFA. The great majority of glucose utilized by ruminants is supplied via gluconeogenesis, with the most important precursor being propionate (Bergman, 1975; Danfaer et al., 1995). Feed restriction decreases plasma glucose levels (Yambayaba et al., 1996; Hornick et al., 2000) in part because of decreased VFA production, which consequently leads to a shift in

energy balance (Brockman and Laarveld, 1986). Glucose levels tend to stay within physiological levels during feed restriction, which may reflect the body's ability to continuously supply glucose during periods of low energy intake. A decrease in glucose level is however evident during severe feed restriction (Gómez-Pastén et al., 1999). There are further reports of hypoglycaemia and ketosis during periods of severe feed restriction (54% of requirement; de Boer et al., 1985). Therefore, it appears that ruminants can adapt to more efficient utilization of available glucose during periods of nutrient restriction.

Adipose tissue lypolysis is caused by an elevated growth hormone (GH) level, which spares use of protein as an energy source (Yambayamba et al., 1986). Also, the severity and(or) length of feed restriction influence the extent of tissue mobilization, and consequently the concentration of NEFA. Yambayamba et al. (1986) noted that as feed restriction progresses, the concentration of NEFA increases in accordance with the decline in energy balance associated with increasing levels of feed restriction. For example, results of Dimarco et al. (1981) and Yambayamba et al. (1986) show 1.6- to 8-fold increases in NEFA concentration after 2 and 6 d of feed restriction, respectively.

Realimentation has opposite effects on glucose and NEFA concentrations compared with feed restriction. For example, glucose concentration increased and NEFA decreased in concentration by d 10 and 8 of realimentation in reports of Yambayamba et al. (1986) and Dimarco et al. (1981), respectively.

Hormones. Decreases in thyroid hormones, triiodothyronine (T_3) and(or) thyroxine (T_4) associated with feed restriction are generally considered responsible for the adaptive decrease in fasting heat production and, consequently, the decrease in maintenance energy requirement (Hayden et al., 1993; Wester et al., 1995; Hornick et al., 2000). Gómez-Pastén et al. (1999), however, reported no change in serum T_4 level, but decreases in serum T_3 and glucose levels occurred in response to increasing levels of feed restriction (60, 80, and 100%, ad libitum intake) over an extended period (36 wk). Decreased T_3 with no change in T_4 have been previously found with low energy diets in both humans (Barrows and Snook, 1985) and dairy cows (Pethes et al., 1985). No change in T_4 has been associated with its conversion to reverse triiodothyronine (rT_3), which in turn has been proposed to be the main route for the reduction in basal metabolism during feed restriction (Gómez-Pastén et al., 1999). It has been further reported that rT_3 causes decreased T_3 levels (Gómez-Pastén et al., 1999) during feed restriction.

Along with decreases in T_3 and T_4 during feed restriction, there are reported decreases in insulin and insulin-like growth factor, with a concomitant increase in plasma GH (Hornick et al., 2000). Increases in plasma GH during feed restriction results from decreased nutrient intake, in turn causing decreased secretion of somatostatin (Thomas et al., 1990), the inhibiting hormone of GH. High levels of GH circulating in the blood during feed restriction lead to fat mobilization, and released fatty acids in part provide energy (Drouillard et al., 1991).

Changes in endocrine hormones during feed restriction affect tissue metabolism, such as a decrease in the protein synthesis:degradation ratio (Hornick et al., 2000). Consequently there is a release of free fatty acids and ketone bodies from adipose tissue and the liver, respectively, which are used by hepatic tissues as energy substrates (Bossart et al., 1985; Jarret et al., 1976). During feed restriction skeletal muscles release lactate and branched-chain keto acids, as well as alanine, glutamine, and branched-chain amino acids (Hornick et al., 2000). Alanine and lactate are important glucose precursors during fasting and feed restriction; increased levels of plasma glutamine and branched-chain amino acids result from proteolysis, while catabolism of branched-chain amino acids leads to increased plasma levels of branched-chain keto acids (Hornick et al., 2000).

Urea. Urea production by hepatocytes during moderate feed restriction is initially increased and then stabilizes, but during severe feed restriction a large transfer of nitrogen to the liver occurs, which is associated with enhanced liver glutamine synthesis (Hornick et al., 2000). Yambayamba et al. (1996) observed lower levels of blood urea-N during feed restriction compared with unrestricted animals, with restriction being a maintenance level of intake for 95 d. During realimentation, blood urea-N level increased within 8-10 d to levels of unrestricted animals (Yambayamba et al., 1996). Ellenberger et al. (1989) reported a decline in blood urea-N during initial stages of compensatory growth,

which may be because of more efficient nutrient utilization and therefore increased growth.

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CHAPTER III

EFFECTS OF FREQUENCY OF SUPPLEMENTATION WITH SOYBEAN MEAL ON PERFORMANCE OF ANGORA DOES CONSUMING LOW-QUALITY FORAGE IN LATE GESTATION AND EARLY LACTATION

ABSTRACT: To determine the effect of supplementation frequency (daily, every 4 d or every 8 d), production state (late gestation and early lactation), and litter size (1 or 2) on performance of Angora goats, 80 does (43.2 ± 0.7 kg initial BW) were used in a split-split plot design experiment. The experiment began at 92 ±18 d of gestation and was 120 d in length, with 15 8-d periods. Coarsely chopped prairie hay (Table 1) was consumed ad libitum without supplementation (C) or with SBM, offered daily (X1) at 0.125% BW (DM), every 4 d (X4), or every 8 d (X8). Ground corn was supplemented at 0.5 to 1.0% BW (DM) in the latter half of the experiment. Body weight on d 31 was lowest ($P < 0.05$) for C vs X1, X4, and X8. On d 57 BW was lower for C ($P < 0.05$) and X8 vs X1 and X4, and ranked ($P < 0.05$) C < X8 < X1 and X4 on d 120. Does with single kids had greater ($P < 0.05$) BW than twin-bearing does on d 57 (41.5 vs 38.7 kg) and 120 (37.3 vs 33.9 kg). Skin follicle activity was not influenced by supplementation frequency, but was lower ($P < 0.05$) on d 120 vs 57 (24.4 vs 28.4/mm^2) and for does with twins than single kids (25.1 vs 27.7/mm^2). Fiber diameter and clean staple strength were similar among supplementation frequencies. Fiber growth rate was similar among dietary treatments on d 0 to 57 but on d 58 to 120 was greater ($P < 0.05$) for X1 than for C and X4. In conclusion, supplementation of

Angora does in late gestation and early lactation consuming low quality forage with soybean meal may be as infrequent as once every 4 d without adversely affecting BW or fiber growth, regardless of litter size. However, with high nutrient requirements during early lactation with both does suckling 1 or 2 kids, less frequent supplementation, such as once every 8 days, may negatively impact BW, and potential exists for slower fiber growth rate with infrequent compared with daily supplementation.

Introduction

To maintain acceptable performance levels, cattle often require supplemental feeding during periods of poor forage production and(or) high nutrient requirements (Huston et al., 1999a). In winter when forage quality is low, if cows are not supplemented they may lose up to 20% of their fall BW by spring (Huston et al., 1993), in turn increasing calving interval. Supplementing animals during periods of low forage production and(or) poor quality is a recommended management practice.

Providing supplements with relatively high CP concentration to ruminants consuming low-quality forage enhances forage use and livestock performance (McCollum and Galyean, 1985; Guthrie and Wagner, 1988; DelCurto et al., 1990). Supplementation is associated with increases in forage digestibility (Del Curto et al., 1990), forage intake (McCollum and Galyean, 1985), and overall animal productivity (Bellido et al., 1981). Feeding supplements daily are often too expensive (Goonewardene et al., 1995). In order to minimize labor costs,

supplementation frequency has been reduced without adverse effects on productivity.

One of the first investigations into the effects of feeding frequency on animal performance was a study by Melton et al. (1960), in which there was no difference in performance of cows supplemented daily, three times per week, or two times per week. More recent studies on supplementation frequency (Beaty et al., 1994; Krehbiel et al., 1998; Huston et al., 1999a and b) have been conducted with sheep or cattle. These reports suggest that ewes and beef cows supplemented as infrequently as once weekly are able to maintain performance levels similar to those supplemented daily, irrespective of stage of production (Huston et al., 1999a; Beaty et al., 1994). Whether Angora does are able to respond similarly to infrequent supplementation during and after gestation is unknown, in part because of their high nutrient requirements for fiber growth.

As goat production increases with increasing demand for goat products, effective management techniques become imperative in supporting one of the fastest growing livestock industries in the U.S.A. Studies on the effects of supplementation frequency may thus be important to goat producers in saving labor and(or) feed expenses. The objective of this study was therefore to examine the effects of no supplementation of mature Angora does and supplementation with soybean meal every 1, 4, or 8 d, during periods when nutrient demands for fetal development and lactation are high, via measurements of feed intake, BW, mohair fiber growth, and other physiological variables. These

findings should identify the lowest frequency of supplementation that allows acceptable levels of production, with minimum labor input.

Materials and Methods

Animal Housing and Dates

This experiment used eighty mature Angora does. Angora bucks were placed with does from October 3 to November 12, 1999. On November 23 at an estimated 45 d of gestation, does were tested for pregnancy and litter size by ultrasonography. A second ultrasound test was conducted on December 7 for females bred the latter part of the breeding period. At 92 ± 18 d of gestation, does were assigned to eight groups, with similar means and variation within group for litter size (single or twins), projected birth date, and BW. The does were then placed in eight, 4 x 10 m pens, with two groups randomly assigned to each of four treatments. After kidding, does whose kids died, that had no milk, or that gave birth to unexpected singles or twins were removed to achieve a total of 56 does. For the first 3 d after kidding, does with their kids were moved to small temporary pens. The experiment lasted 120 d, from January 12 to May 10, 2000, consisting of 15 8-d periods.

Feeding and Treatments

Coarsely chopped prairie hay was offered daily in wooden feeders for ad libitum consumption (Table 1). All does had free access to fresh water and trace mineralized salt blocks. On the last day of each 8-d period, orts were removed and weighed. Does were supplemented with soybean meal (SBM) in separate feeders. Supplement treatments were no supplementation (C), daily

supplementation (X1), supplementation every 4 days (X4), and supplementation every 8 days (X8). For the X4 group, SBM was supplemented on d 1 and 5 of the 8-d period, and on d 1 for X8. The daily rate of SBM supplementation for X1, X4, and X8 was 0.125% BW (DM basis); therefore, on respective days of supplementation, X1, X4, and X8 does received 0.125, 0.5, and 1.0% BW, respectively. In addition to SBM, after kidding all does were supplemented with corn at a daily rate of 0.5% BW as well as given continued access to trace mineralized salt blocks. This was achieved with a temporary division in the pen separating does that had kidded from those that had not. However, starting February 28 (d 49), because of the apparent poor condition of a number of does, the daily corn supplement was given to all does. The first doe kidded on February 28, 2000 (d 49) in period 7, and the last kidded on April 3 in period 11 (d 82). Moreover, because of low BW, poor health, and death of some kids, as well as poor body condition of does in lactation, the daily level of supplemental corn was doubled from 0.5 to 1% BW on March 16, 2000 (d 65, period 9) and continued at this level to the end of the experiment (d 120). These adjustments, were made because of lower hay quality than expected.

All does were treated for internal parasites (4 cc Ivomec, Merk Ag Vet Division, Rahway, NJ) on January 19, 2000, and received 1st and 2nd vaccinations for *Corynebacterium pseudotuberculosis* (2.5 cc U-Bac 8, Colorado Serum Co., Denver, CO) on January 19 and February 28, 2000, respectively. Does were hoof-trimmed on February 3, 2000 and kids received 3 cc of Panacur (Colorado, Serum Co., Denver, CO) and 2 cc of CD&T vaccine (Colorado, Serum

Co., Denver, CO) vaccine for *Clostridium perfringens* type C and D and tetanus toxoid on May 10, 2000.

Measurements and Sampling

BW. Does were weighed on d 0, d 31, d 57, immediately after kidding, and at the end of the experiment (d 120). On d 31, none of the does had kidded, whereas by d 57 approximately one-half had kidded and d 120 was 4 week after the last doe kidded. Kids were weighed at birth.

Feed and Orts. Feedstuffs were grab sampled at the start of each period before feeding, and samples were placed in labeled bags and stored below –20°C. Hay orts were sampled during period 5 (d 33-40 of the experiment), placed in labeled bags, and stored below –20°C. Total consumption of SBM and corn was assumed.

Skin and Fleece. Does were shorn 2 week before and 2 weeks after the experiment, at which time fleece weight was recorded and a grab sample was taken. In addition, a 100-cm^2 left side patch was clipped (Oster blade no. 40) on d 0, 57, and 120 to determine mohair growth and yield, and a skin biopsy (8 mm; P250, Acuderm, Ft. Lauderdale, FL) sample was taken to assess skin histological characteristics (ASTM, 1988). Skin biopsy samples were taken under local anesthesia (1 mL lidocaine) and close to the site of fiber patch samples. Tissue samples were placed in labeled cassettes and preserved in phosphate buffered formalin for a minimum of 48 h before analysis.

Blood and Ruminal Fluid. Blood and ruminal fluid samples were collected in periods 4 and 12 at approximately 4 h after feeding. These periods

were chosen because no does had kidded in period 4, and kidding was complete by period 12. All does were sampled on d 1 of the period, which was the day of supplementation for X1, X4, and X8. The day of the period for sampling C and X1 was not anticipated to influence blood or ruminal fluid measures. Conversely, to address likely differences among days for X4 and X8, additional samples were taken. For both X4 and X8 does, samples were taken on d 4, which was 3 d after supplementation. The X8 does were also sampled on d 7, which was 6 d after supplementation. To minimize stress and avert potentially negative effects on feed intake, C and X1 were not sampled on these days. Blood was collected using 22 gauge, 2.54-cm long needles by jugular venipuncture into two 10-mL vacutainers (Becton Dickinson, Franklin Lakes, NJ), one containing heparin and the other potassium oxalate-sodium chloride. Following collection, samples were chilled in ice for approximately 1 h and centrifuged (J-6B Centrifuge; Beckman Instruments, Inc. Fullerton, CA) at 2,400 x *g* for 25 min at 4°C. After centrifuging, approximately 3 mL of plasma was withdrawn using a pipette and divided into 1.5-mL micro centrifuge tubes (Fisher Scientific, Pittsburgh, PA) and then stored below -20 °C until analysis. Ruminal fluid was sampled via stomach tube into two tubes, one with 1mL of 25% (wt/vol) metaphosphoric acid for VFA analysis, and the other with 2 mL of 4% (wt/vol) trichloroacetic acid for ammonia analysis.

Laboratory Analyses

Feed. Feedstuffs were dried at 55°C for a minimum of 48 h and ground in a Willey mill to pass a 1-mm screen. Feed and ort samples were analyzed for

DM, ash (AOAC, 1990), CP (Technicon Instrument Co., Tarrytown, NY), NDF, ADF, and ADL (filter bag technique; ANKOM Technology Corp., Fairport, NY).

Skin and Fleece. Mohair patch samples collected on d 0, 57, and 120 were weighed for grease fleece weight and evaluated for laboratory scoured (clean) yield and fiber diameter. Samples measured weighed between 5 to 25 g and scoured (clean) yield was calculated as (weight of bone-dry, washed mohair / weight of grease mohair) x 100 x 1.1123, in which 1.1123 is an adjustment factor for plant material not removed by scouring (ASTM, 1988). Staple length and strength were determined for d 120 only, since samples collected on d 0 and 57 were too short and not suited for proper analysis. Staple length was determined by standard procedures of ASTM (1988). Grease and clean staple strength was determined using an Agritest Staple Beaker System (Agritest Pty, Sydney Australia) at the San Angelo Texas A&M University Research Station. Staple strength of grease and clean mohair was analyzed as the maximum load (Newtons) needed to break a staple. To correct for differences in the size of the staple tested, measurements were standardized by the linear density (grams/centimeter = kilotex) of grease or clean mohair. Fiber diameter was measured on samples collected on patch samples using an optical fiber distribution analyzer (OFDA 100; Zellweger Uster, Inc., Charlette, NC).

Skin samples were processed overnight through a 12-step process of graded concentrations of ethanol, choroform, xylene, and paraffin wax using a Citadel tissue processor (Shandon Inc., Pittsburg, PA). After step 12, skin samples were immediately embedded with the epidermal surface uppermost into

a mold of paraffin-polymer wax, using a Histocenter II Embedder (Shandon, Pittsburg, PA). The embedded skin was transversely sectioned into 8-μm thick layers of wax ribbons starting from the epidermal surface to the base of the hair follicles. The sectioned samples were mounted onto slides with at least five sectioned samples per slide. Once mounted, samples were stained using the adapted Sacpic stain method (Nixon, 1993). Approximately 10 follicle bundles were then scored under the microscope for number of active and inactive primary and secondary follicles, from which the percentages of active and inactive primary and secondary follicles, follicle density, and ratio of primary to secondary follicles were calculated (Nixon, 1993).

Blood and Ruminal Fluid. Plasma samples were analyzed for glucose and urea via colorimetric assays with a Technicon Auto Analyzer II System (Technicon Instruments, Tarrytown, NY). Nonesterfied fatty acids were determined with a commercial kit using an enzymatic colorimetric procedure (Wako Pure Chemical Industries, Richmond, VA). Amino acid concentrations were determined as described by Puchala et al. (1995) using an AminoQuant system (Hewlett Packard Co., San Fernando, CA).

Ruminal fluid was analyzed for ammonia by the phenol-hypochlorite colorimetric procedure of Broderick and Kang (1980). VFA concentrations were analyzed by gas chromatography as described by Lu et al. (1990).

Statistical Analysis

Pre-kidding data collected from does removed from the experiment were retained for analysis of late gestation measures but were omitted from early

lactation analyses. Data were analyzed as a split-split-plot design, with a main plot of dietary treatment, a subplot of litter size, and a sub-subplot of phase (i.e., gestation and lactation) or day of measurement, using the MIXED model procedure of SAS (SAS Inst. Inc., Cary, NC). Effects of supplementation frequency, production state, and litter size on BW and skin tissue and patch sample measures were analyzed with a model consisting of supplementation frequency, litter size, supplementation frequency x litter size, phase or day, supplementation frequency x phase, litter size x phase or day, and supplementation frequency x litter size x phase or day. Random sources of variation considered were group x supplementation frequency and animal x group x supplementation frequency. Furthermore, measurements taken on d 0, such as BW and skin measures, were used as covariates.

For ruminal fluid and blood measures with samples taken on different days of supplementation intervals, the mean of values on different days and those on d 1 were analyzed as described above. To assess differences between or among days for X4 and X8 does, data were analyzed within treatment with a model consisting of litter size, phase, litter size x phase or day, and the random effect of group. For d 4 and 7, the model terms were litter size, phase or day, litter size x phase or day, and the random effect of group. Treatment means were separated by least significant difference when overall F-values were significant ($P < 0.05$).

Because of differences in the number of observations and levels of supplemental grain, separate supplementation frequency and litter size means and SE are presented for the different phases or days. When interactions

involving supplementation frequency and litter size were significant, interaction means are presented; main effects means are given with nonsignificant interactions regardless of significance.

Results and Discussion

Doe BW

Initial BW was 42.0 ± 1.02 and 44.3 ± 0.84 kg for does bearing single and twin kids, respectively. Doe BW for all treatments decreased during the experiment, with the magnitude of loss ranking ($P < 0.05$) C > X1 and X4 > X8 (Table 2). Doe BW after kidding was lowest among treatments ($P < 0.05$) for C but was similar among X1, X4, and X8. Moreover, twin bearing does lost more BW than does with single kids.

There were two-way interactions between day of weighing (i.e., d 31, and 57) and supplementation frequency and litter size (Table 3). On d 31 (2 weeks prior to the first kidding), X8 does were similar in BW to X1 and X4 does, but were lower ($P \leq 0.05$) in BW on d 57 (during kidding) and 120 (24 d after the last doe kidded). Compared with C, BW for X8 was greater ($P < 0.05$) on d 31 and 120 but similar on d 57 ($P = 0.11$). There was a difference in BW between does bearing twins vs singles on d 57 and 120 ($P < 0.01$) though not on d 31 ($P = 0.80$).

Lower BW loss for supplemented than unsupplemented does is in agreement with similar reports for other ruminant species. Pregnant ewes supplemented at 1-, 4-, or 7-d intervals lost less BW compared with unsupplemented ewes (Huston et al., 1999a). Huston et al. (1999b) noted

greater BW gain by beef cows supplemented with CSM daily, three times weekly, or once weekly than by control cows. Similarly, when given a corn/cottonseed meal supplement, Angora kids had greater BW gain than ones not supplemented (Huston et al., 1993). Farmer et al. (2001), Ebro et al. (1998), Okello et al. (1996), and Beaty et al. (1994) also reported improved BW gain when supplements high in protein were fed compared with supplements of lower protein concentration or no supplementation.

Similar BW change and live BW between X1 and X4 supports findings of Huston et al. (1999a) in which supplementation of pregnant ewes daily or every 4 d resulted in similar BW change after fall and winter lambing seasons and of Huston et al. (1999b) in which there were no differences in BW change of pregnant cows supplemented daily, three times per week, or weekly. Greater BW loss and lower BW for X8 vs X1 and X4 contrast the report of Huston et al (1999a) in which BW change of pregnant ewes supplemented weekly was not different from that with supplementation daily or every 4 d.

As indicated by the difference between initial BW and BW on d 31 and by BW change over the entire experiment, the loss of BW over time may have resulted from greater nutrient requirements during lactation vs gestation (Schingoethe et al., 1988). In accordance, the X8 supplementation treatment appeared acceptable relative to more frequent supplementation during gestation but not in lactation with elevated nutrient demands. Conversely, the X4 treatment relative to daily supplementation (X1) was acceptable in regards to BW change in both production states. In contrast to findings of the present experiment, Beaty et

al. (1994) reported that cows supplemented three times weekly loss more BW during gestation (75 d before calving) than those supplemented daily, although there was no difference in BW during subsequent periods.

Differences in doe BW between litter sizes reflect the increased nutrient demands associated with suckling of multiple vs single kid litters (Schingoethe et al., 1988). Lower birth weight for twin than single kids along with similar doe BW on d 31 implies little effect of litter size on nutrient needs in gestation. The lack of interaction between supplementation frequency and litter size may indicate that the interaction between supplementation frequency and day of BW measurement relates to a threshold effect on the increase in nutrient demands with the onset of lactation.

Kid BW

Birth weight was greater for single vs twin kids ($P < 0.05$; Table 2). No explanation is apparent for greater ($P \leq 0.05$) birth weights for X4 vs C and X1. Conversely, Thomas et al. (1991) reported no difference in lamb birth and weaning weights between ewes supplemented with 21% CP pellets daily or every alternate day. Likewise, Beaty et al. (1994) and Farmer et al. (2001) found similar calf birth weight for cows supplemented daily or 2, 3, or 5 d weekly. Kid BW at the end of the experiment was not different among treatments ($P = 0.3$).

Feed Intake

Dry matter intake in the different phases of the experiment was numerically greater for treatments with than without supplementation (Table 4). Total intake averaged across phases was greater ($P < 0.05$) for X1, X4, and X8

compared with C. In agreement, Huston et al. (1999b) observed similar DMI among cows supplemented daily or three times or once weekly. Krehbiel et al. (1998) reported no difference in total intake by ewes between daily and three times weekly supplementation. In contrast, Huston et al. (1999a) observed that supplementation every other day depressed DMI by mature ewes compared with daily supplementation. Collins and Pritchard (1992) found no difference in DMI by wethers supplemented daily or every other day, and Calhoun et al. (1988) also reported similar DMI with supplementation intervals of 1, 2, 3, 4, and 5 d.

Ruminal Ammonia Nitrogen

Mean ruminal ammonia N concentrations when sampled during gestation (Table 5) were near 5 mg/100 mL, suggested by Satter and Slyter (1974) as the concentration necessary for maximum bacterial growth with non-protein N supplements. Mean concentration during gestation was lower ($P < 0.05$) for C vs X4 and X8, although mean concentrations for X4 and X8 treatments are largely influenced by the particular days chosen for sampling. There was an interaction between supplementation frequency and litter size ($P < 0.05$) in mean ammonia N concentration during lactation. Mean concentration was similar among treatments for does with single kids. However, the concentration for does with twin kids was lowest among treatments for C ($P < 0.05$). On d 1 of gestation and lactation, when all treatment groups were supplemented, ruminal ammonia N concentration was similar between C and X1. This was somewhat surprising considering greater N intake for X1. Although, samples were taken 4 h after feeding, which may have been later than peak concentration resulting from

degradation of protein of SBM. Because of the high amount of SBM fed on d 1 for X8, the ammonia concentration was greater ($P < 0.05$) than for C and X1 in both gestation and lactation, but was similar to the concentration for X4 in gestation. Litter size did not influence ammonia N concentration on d 1 or mean concentration in gestation.

On d 4 of the period, during both gestation and lactation, ruminal ammonia N concentration for X4 was less than on d 1 (Table 6). Similar findings were observed for X8, with levels on d 4 and 7 not different but lower than on d 1 of gestation and lactation ($P < 0.05$).

Ruminal ammonia N levels in this experiment follow response patterns similar to previous reports. On days when both daily and every third day supplemented steers were fed, ammonia N concentrations were higher in the less frequently supplemented steers (Beaty et al., 1994). Similarly, on days when all treatment groups were fed, Collins and Pritchard (1992) reported higher ruminal ammonia N concentration in wethers supplemented every second day than in wethers supplemented daily, and Farmer et al. (2001) observed a higher concentration in cows supplemented twice weekly than daily. Previous studies furthermore show day x supplementation frequency interactions, in which infrequently supplemented animals had higher concentrations on the first 2 d after supplementation compared with concentrations in animals supplemented daily (Collins and Pritchard, 1992; Beaty et al., 1994; Farmer et al., 2001).

Plasma Urea Nitrogen

Day 1 and mean plasma urea N concentrations were not different among dietary treatments (Table 7), which is in contrast to differences in ammonia N levels. Plasma urea N concentration for X4 does was greater ($P < 0.05$) on d 1 vs 4 in gestation, although the concentration was similar between days in lactation (Table 8). For X8 does, in gestation plasma urea concentration ranked d 1 > 4 > 7 ($P < 0.05$). However, a different ranking ($P < 0.05$) was noted in lactation (d 1 > 7 > 4). The plasma urea concentration was not affected by litter size, except for a lower level in X8 does for single- vs twin-kid litters.

Contrary to findings of this experiment, Huston et al. (1999a and b) and Beaty et al. (1994) reported that in animals supplemented every 3 or 7 d, plasma urea N concentration at 2 d after supplementation was greater than in unsupplemented controls and animals supplemented daily. Similar plasma urea levels among treatments on d 1 of the present experiment may be explained by a delayed response (e.g., 6-8 h) to infrequent supplementation, as suggested by Beaty et al. (1994) and Farmer et al. (2001).

Ruminal pH

All pH values fell within a range of 6.2-7.0, typical of high roughage diets (Owens and Goetsch, 1988). On d 1 during gestation, when all supplemented does received SBM, pH for X8 and X4 was lower ($P < 0.05$) than for C, with X1 ruminal pH being intermediate (Table 9). Mean ruminal pH during gestation was lowest among treatments for X1 ($P < 0.05$); however, values during lactation were similar among treatments. The most likely explanation for decreased pH among supplemented does in some instances is increased microbial activity and

VFA production. Similarly, Beaty et al. (1994) found lower ruminal pH in infrequently supplemented cows on days of supplementation compared with values in animals supplemented daily. Day of sampling did not influence pH in X4 and X8 does (Table 10).

Volatile Fatty Acids

The mean total VFA concentration during gestation was greater ($P < 0.05$) for X1, X4, and X8 than for C (Table 11). A similar trend was evident on d 1 of gestation (treatment F-value, $P < 0.08$). Conversely, mean concentrations were similar among all groups during lactation. There was a litter size x supplementation frequency interaction on d 1 ($P < 0.05$). During gestation, X4 and X8 had total VFA concentration higher on d 1 ($P < 0.05$) than on d 4. Day of sampling in lactation did not affect total VFA concentration in X8 does (Table 12). For X4 does in lactation there was a litter size x sampling day interaction in total VFA concentration, with lower and greater levels on d 1 vs 4 for does with singles and twins, respectively. One of the factors causing greater VFA concentration for supplemented vs C does in some cases is the highly fermentable nature of SBM, in addition the supply of nitrogenous compounds for microbial growth and digestion. That mean VFA concentration did not differ among treatments during lactation as in gestation may partially be because of daily corn supplementation.

The acetate:propionate ratio (A:P; mean and d 1 values) was greatest ($P < 0.05$) among treatments for X1 does in all but one instance (Table 13). Contrary to these findings, Collins and Pritchard (1992) did not observe effects of supplementation frequency on molar proportions of the major VFA. The A:P ratio

for X4 and X8 was not influenced by day of sampling, except for a greater ratio on d 4 vs 1 in gestation for X4 does (Table 14). Litter size did not affect the A:P ratio.

Glucose

Glucose concentration on d 1 was higher ($P < 0.05$) during gestation than lactation (57.4 vs 40.0 mg/dL; Table 15). Glucose concentration on d 1 was similar among supplementation frequencies. Mean glucose concentration was not affected by dietary treatment during gestation, but during lactation was greatest among dietary treatments ($P < 0.05$) for X8. The only litter size effect noted was a high concentration on d 1 during gestation for litter size 1 vs 2 ($P < 0.05$). For X4, glucose concentration was greater on d 4 than on d 1 of gestation ($P < 0.05$); however, values were similar during lactation (Table 16). Conversely, glucose concentration during lactation for X8 ranked ($P < 0.05$) d 7 > 1 > 4 but was similar among days during gestation.

Higher glucose concentrations during gestation compared with lactation in this experiment agree with findings of Davis et al. (1979) in which it is reported that mammary glucose uptake by goats on the day after parturition was nine times that on d 7 to 9 prepartum, and five times that on d 2 prepartum. The authors concluded that the magnitude and timing of this increase in glucose uptake is an important index of the onset of copious milk secretion because glucose is required for lactose synthesis and lactose is the most important osmotic solute in milk. Similar findings were reported by Bell (1995), in which the

mammary requirement for glucose was 2.7 times that of the gravid uterus during late gestation.

In agreement with findings of this study, Tovar-Luna et al. (1995) reported that ewes supplemented every other day had glucose concentrations similar to daily supplemented ewes. It was suggested that nutrient absorption by ewes supplemented on alternate days may be buffered by the reticulo-rumen, which acts as a reservoir to lessen temporal variation in absorption of glucose precursors.

NEFA

Blood concentrations of NEFA can be reflective of the nutritional status of animals. Mean concentrations of NEFA were higher ($P < 0.05$) during lactation than gestation (763 vs 534 μEq/L; Table 17). Mean and d 1 NEFA concentrations were similar among supplementation frequencies in lactation even though BW loss during lactation was greatest for C. However, in gestation mean and d 1 NEFA levels were greatest among treatments ($P < 0.05$) for C. Similar to differences among NEFA concentrations for supplementation frequencies, NEFA levels (mean and d 1) in lactation were not different between litter sizes but were greater ($P < 0.05$) for does with twin vs single kids in gestation. These differences in gestation but not lactation disagree with greater BW loss in lactation than gestation, which perhaps in part may relate to corn supplementation in lactation. The only effect of sampling day on NEFA concentrations for X4 and X8 does in lactation involved an interaction between production state and litter size. The NEFA level for X4 in lactation was greater ($P < 0.05$) on d 4 vs 1 in does with twin

kids (Table 18). Also, NEFA concentration in gestation was greater for litter size 2 vs 1 in X8 does. Greater NEFA concentrations during lactation vs gestation may reflect increased energy requirements (Schingoethe et al., 1988). Likewise, greater NEFA levels for C vs X1, X4, and X8 may have been due to lower energy intake for C, which elevated fat mobilization. However, it was expected that differences in NEFA concentrations among dietary treatments would have been more likely and pronounced in lactation compared with gestation.

Plasma Amino Acids

Aspartate, glycine, and tyrosine were the only amino acids with concentrations not affected by litter size, supplementation frequency, and production state (Figures 1, 2, and 3, respectively). Glutamine concentration on d 1 was greatest among supplementation frequency treatments ($P < 0.05$) for X8, although mean concentration was only greater for X8 vs C ($P < 0.05$; Figure 4). For serine there was an interaction between supplementation frequency and litter size ($P < 0.05$; Table 19). For single-kid bearing does in gestation, X4 had the greatest serine concentration ($P < 0.05$), whereas there were no differences for does with twins. Alanine concentration on d 1 of the period during gestation was lower for does with singles than twins ($P < 0.05$), although mean values were similar (Figure 6). Among the amino acids affected by supplementation frequency, there was only one essential amino acid. Arginine concentration on d 1 during gestation was greater for X8 and X1 vs X4 and C ($P < 0.05$); however, mean values for X8, X1, and C were greater than for X4 ($P < 0.05$; Figure 7). Relatively higher concentrations of glutamine and arginine in X8 does on d 1

during gestation may simply be due to greater amounts of SBM fed to the X8 does. Similar trends for less frequently supplemented does were found for other nonessential amino acids (i.e., aspartate, serine, glycine, and alanine).

There were essential amino acids with higher concentrations during gestation than lactation, namely arginine, threonine, valine, methionine, phenylalanine, isoleucine, leucine, and lysine (Figures 7, 8, 9, 10, 11, 12, 13, and 14, respectively). Lower concentrations during lactation are most likely due to increased utilization compared with gestation. Nursing ewes especially those with twins may have a 50-60% increase in protein requirements relative to late gestation (Schingoethe et al., 1988). Amino acids also provide 50 to 55% of energy used by the developing fetus (Bell, 1995), which is further supported by evidence that fetal protein deposition only accounts for approximately 50% of the fetal net uptake of amino acids in sheep (Lemons et al., 1976) and cattle (Ferrell, 1991).

Skin and Hair Characteristics

There were no differences among supplementation frequency treatments in skin follicle measures (Table 20). There was no litter size effect in apparent total follicle density for periods of d 0-56 and 56-120. Averaged values were however higher in single bearing does vs those with twins ($P < 0.05$), as well as at the end of the experiment than on d 57. Similarly, the ratio of primary to secondary follicles was not impacted by litter size during individual periods; average values were however lower for does with twins vs singles ($P < 0.05$).

There was no treatment or litter size effect on primary and secondary follicle activities, or their ratio.

Fiber growth rate was greater ($P < 0.05$) from d 58 to 120 than from d 0 to 57 (Table 21). There were no differences among treatments in fiber growth on d 0 to 57; however, growth was greater for X1 vs C and X4 on d 58-120 ($P < 0.05$). Clean yield was not influenced by supplementation frequency or by litter size. Fiber diameter was considerably lower from d 0 to 57 than d 58 to 120 ($P < 0.05$), but was similar among supplementation frequencies and between litter sizes. Clean staple strength was not affected by supplementation frequency or litter size.

Fiber growth and characteristic measures of the present experiment are in general agreement with the report of Morcombe et al. (1988), in which supplementation frequency had no effect on wool growth, mean fiber diameter, clean yield, or mean staple strength. Morcombe et al. (1988) noted that wool growth was affected by production state, with mean length of wool grown per day lowest before and immediately after lambing (0.197 – 0.201 mm/d) and higher in later stages of lactation (0.206 – 0.214 mm/d), similar to the difference in fiber growth rate noted in the present experiment. Likewise Calhoun et al. (1988) did not alter mohair fleece production, fiber diameter, or number of medullated (med and kemp) fibers in male Angora goats by supplementing every 1, 2, 3, 4, or 5 d.

Implications

Angora does in late gestation and early lactation consuming low quality forage can be supplemented with protein as infrequently as once every 4 days

without adversely affecting BW. Less frequent supplementation, such as once every 8 days, may be as effective as supplementation daily or every 4 days with moderate nutrient requirements of late gestation. However, in early lactation with elevated nutritional demands, supplementation once every 8 days can increase BW loss compared with more frequent supplementation, although nutrient needs as impacted by litter size did not influence BW response to supplementation frequency. Skin and fiber characteristics were not influenced by infrequent supplementation, except for an improvement in fiber growth rate with daily supplementation between d 58 and 120. This suggests a need for more frequent supplementation to stimulate fiber production when nutrient demands are high during lactation.

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Table 1. Nutrient composition of feedstuffs consumed by Angora does (% DM).

Item	Hay	SBM[1]	Corn
Ash	5.1	9.2	1.4
CP	4.4	48.3	8.5
NDF	66.2	15.6	14.3
ADF	46.1	9.8	4.5
ADL	12.6	3.4	3.5

[1]SBM = soybean meal

Table 2. Effects of supplementation frequency and litter size on body weight change of Angora does, body weight after kidding, kid birth weight, and kid weight (kg) at the end of the experiment[1].

Item	Supplementation frequency[2]					Litter size		
	C	X1	X4	X8	SE	1	2	SE
Change in doe BW	-11.9[c]	-5.4[a]	-5.6[a]	-9.1[b]	0.82	-6.4[b]	-9.6[a]	0.59
BW after kidding	34.6[a]	39.2[b]	38.3[b]	38.6[b]	1.20	38.4	37.0	0.83
Kid birth weight	2.5[a]	2.6[a]	3.1[b]	2.9[ab]	0.12	3.2[b]	2.3[a]	0.08
Kid final BW	5.7	6.5	6.7	6.8	0.36	7.3[b]	5.5[a]	0.33

[a,b,c]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]15 8-d periods, with kidding in periods 6-10.
[2]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 3. Effect of supplementation frequency, litter size, and day of the experiment on body weight (kg) of Angora does.

Day[1]	Supplementation frequency[2]					Litter size		
	C	X1	X4	X8	SE	1	2	SE
Day 31	43.3[a]	46.0[b]	46.2[b]	45.9[b]	0.74	45.4	45.2	0.53
Day 57	37.7[a]	41.5[b]	41.8[b]	39.3[a]	0.75	41.5[b]	38.7[a]	0.53
Day 120	31.5[a]	38.5[c]	37.7[c]	34.7[b]	0.84	37.3[b]	33.9[a]	0.60

[a,b,c]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Day 31 = gestation; day 57 = approximately one-half does in late gestation and one-half in early lactation; day 120 = end of experiment, lactation.
[2]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 4. Effects of supplementation frequency and production state on dry matter intake (kg) by Angora does.

Item	Production state[1]	Supplementation frequency[2]				SE
		C	X1	X4	X8	
Total	Gestation	0.97	1.11	1.07	1.14	0.052
	During kidding	0.98	1.23	1.25	1.13	0.061
	Lactation	1.07	1.42	1.41	1.41	0.095
	Mean	1.00[a]	1.25[b]	1.24[b]	1.23[b]	0.042
Forage	Gestation	0.97	1.05	1.01	1.08	0.052
	During kidding	0.68	0.85	0.85	0.76	0.047
	Lactation	0.71	1.03	1.02	0.99	0.083
	Mean	0.79	0.97	0.96	0.94	0.039

[1]The experiment consisted of 15 8-d periods; gestation = periods 1-6; during kidding = periods 7-11 (approximately one-half of the does had kidded on d 57 in period 8); lactation = periods 12-15.
[2]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 5. Effects of supplementation frequency, litter size, and production state on ruminal ammonia N concentration (mg/dL) in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	3.2[a]	4.0[a]	9.9[b]	12.8[b]	1.00	7.6	7.4	0.64
	Lactation	1.5[a]	4.6[a]	6.4[a]	12.3[b]	1.36	5.7	6.8	0.79
Mean	Gestation	3.2[a]	4.0[ab]	6.2[bc]	6.9[c]	0.71	5.2	5.0	0.44
	Lactation								
	Litter size 1	2.2	2.8	3.4	4.9	1.41			
	Litter size 2	0.9[a]	6.0[b]	4.5[b]	4.7[b]	1.31			

[a,b,c] Means in a row, without a common superscript letter differ ($P < 0.05$).
[1]Day (8-d periods): 1 = day of supplementation; mean = average from all samples (C and X1, sampled on d1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 6. Effects of day of the period on ruminal ammonia N concentration (mg/dL) in Angora does supplemented every 4 or 8 days.

Supplementation	Production	Day of the period[3]				Litter size		
frequency[1]	state[2]	1	4	7	SE	1	2	SE
X4	Gestation	9.9^{b}	2.4^{a}		1.4	5.8	6.5	1.47
	Lactation	6.4^{b}	1.8^{a}		1.15	3.7	4.5	1.23
X8	Gestation	12.8^{b}	2.8^{a}	4.2^{a}	0.80	7.1	6.2	0.82
	Lactation	12.5^{b}	0.7^{a}	0.2^{a}	1.11	4.2	4.8	1.07

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]X4 does were supplemented on d 1 and 5, and X8 does were supplemented on d 1, 4, and 7 of the 8-d periods.

Table 7. Effects of supplementation frequency, litter size, and production state on blood urea N concentration (mg/dL) in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	12.1	12.6	12.1	12.7	1.2	11.8	12.9	0.7
	Lactation	5.7	11.3	11.0	12.8	2.5	10.0	10.3	1.4
Mean	Gestation	12.1	12.6	10.9	9.7	1.2	11.0	11.6	0.7
	Lactation	5.7	11.3	9.2	9.1	1.3	9.0	9.0	0.8

[1]Day (8-d periods): 1 = day of supplementation; mean = average of all samples (C and X1, sampled on d 1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 8. Effects of day of the period on blood urea N concentration (mg/dL) in Angora does supplemented every 4 or 8 days.

Supplementation	Production	Day of the period[3]				Litter size		
frequency[1]	state[2]	1	4	7	SE	1	2	SE
X4	Gestation	12.2[b]	9.8[a]		0.73	10.6	11.4	0.81
	Lactation	10.4	9.2		2.26	10.6	9.0	2.47
X8	Gestation	12.7[c]	9.4[b]	7.0[a]	0.99	8.4[a]	11.1[b]	1.00
	Lactation	13.1[c]	4.8[a]	8.6[b]	2.19	7.8	9.9	2.17

[a,b,c]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]X4 does were supplemented on d 1 and 4, and X8 does were supplemented on d 1, 4, and 7 of the 8-d period.

Table 9. Effects of supplementation frequency, litter size, and production state on ruminal pH in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	6.58[c]	6.42[bc]	6.34[ab]	6.23[a]	0.048	6.43[b]	6.35[a]	0.030
	Lactation	6.45	6.33	6.33	6.33	0.043	6.36	6.36	0.028
Mean	Gestation	6.58[b]	6.42[a]	6.41[a]	6.45[a]	0.033	6.50[b]	6.43[a]	0.023
	Lactation	6.45	6.33	6.42	6.39	0.047	6.40	6.39	0.030

[a,b,c] Means in a row without a common superscript letter differ ($P < 0.05$).

[1]Day (8-d periods): 1 = day of supplementation; mean = average of all samples (C and X1, sampled on d 1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).

[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.

[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 10. Effects of day of the period on ruminal pH in Angora does supplemented every 4 or 8 days.

Supplementation	Production	Day of the period[3]				Litter size		
frequency[1]	state[2]	1	4	7	SE	1	2	SE
X4	Gestation	6.34	6.49		0.031	6.42	6.41	0.027
	Lactation	6.33	6.51		0.054	6.43	6.41	0.049
X8	Gestation	6.23	6.59	6.52	0.046	6.49	6.41	0.047
	Lactation	6.33	6.44	6.25	0.045	6.31	6.36	0.038

[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]X4 does were supplemented on d 1 and 4, and X8 does were supplemented on d 1, 4 and 7 of the 8-d period.

Table 11. Effects of supplementation frequency, litter size, and production state on total volatile fatty acid concentration (m*M*) in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	42.9	61.9	74.4	80.9	5.12	66.9	63.1	3.40
	Lactation								
	Litter size 1	60.9[a]	71.6[ab]	84.5[b]	90.2[b]	6.86			
	Litter size 2	64.2[b]	66.4[b]	37.7[a]	89.4[c]	5.92			
Mean	Gestation	42.6[a]	61.7[b]	66.3[b]	61.8[b]	3.40	58.5	57.7	2.39
	Lactation	62.4	67.0	60.5	73.0	4.23	69.2	63.3	3.00

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Day (8-d periods): 1 = day of supplementation; mean = average of all samples (C and X1, sampled on d 1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 12. Effects of day of the period on total volatile fatty acid concentration (m*M*) in Angora does supplemented every 4 or 8 days.

Supplementation frequency[1]	Production state[2]	Day of the period[3]				Litter size		
		1	4	7	SE	1	2	SE
X4	Gestation	75.2[b]	55.1[a]		5.53	73.8	56.5	5.52
	Lactation							
	Litter size 1	84.5[b]	59.9[a]		6.03			
	Litter size 2	37.7[a]	59.8[b]		7.78			
X8	Gestation	80.8[b]	42.8[a]		3.33	62.4	61.3	3.70
	Lactation	89.8	60.5	68.7	10.17	72.3	73.7	6.93

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]X4 does were supplemented on d 1 and 4, and X8 does were supplemented on d 1, 4, and 7 of the 8-d period.

Table 13. Effects of supplementation frequency, litter size, and production state on acetate:propionate in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	4.91[c]	5.34[d]	4.41[b]	3.72[a]	0.134	4.68	4.51	0.095
	Lactation								
	Litter size 1	3.46	4.31	4.01	3.19	0.311			
	Litter size 2	3.49[b]	4.37[c]	1.93[a]	3.64[b]	0.284			
Mean	Gestation	4.91[b]	5.34[c]	4.92[b]	4.56[a]	0.132	5.00	4.86	0.093
	Lactation	3.47[a]	4.34[b]	3.40[b]	3.50[b]	0.247	3.70	3.65	0.176

[a,b,c,d]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Day (8-d periods): 1 = day of supplementation; mean = average of all samples (C and X1, sampled on d 1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 14. Effects of day of the period on acetate:propionate in Angora does supplemented every 4 or 8 days.

Supplementation	Production	Day of the period[3]				Litter size		
frequency[1]	state[2]	1	4	7	SE	1	2	SE
X4	Gestation	4.41[a]	5.51[b]		0.194	5.02	4.91	0.215
	Lactation	2.97	3.84		0.694	3.81	2.99	0.707
X8	Gestation	3.72	5.40		0.094	4.6	4.52	0.109
	Lactation	3.42	3.17	3.86	0.471	3.23	3.74	0.371

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]X4 does were supplemented on d 1 and 4, and X8 does were supplemented on d 1, 4, and 7 of the 8-d period.

Table 15. Effects of supplementation frequency, litter size, and production state on plasma glucose concentration (mg/dL) in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	50.4	60.5	54.4	64.3	6.00	60.5[b]	54.3[a]	3.20
	Lactation	38.6	40.1	39.2	37.9	3.20	39.8	38.2	2.30
Mean	Gestation	50.5	60.5	59.9	72.5	8.11	63.9	57.8	6.30
	Lactation	38.6[a]	40.2[a]	38.2[a]	51.7[b]	2.00	43.0	41.4	1.40

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Day (8-d periods): 1 = day of supplementation; mean = average of all samples (C and X1, sampled on d 1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 16. Effects of day of the period on plasma glucose (mg/dL) in Angora does supplemented every 4 or 8 days.

Supplementation	Production	Day of the period[3]				Litter size		
frequency[1]	state[2]	1	4	7	SE	1	2	SE
X4	Gestation	54.5[a]	65.2[b]		3.76	64.3	55.4	4.50
	Lactation	38.8	34.0		5.07	40.5	32.3	5.10
X8	Gestation	64.5[b]	57.2[b]	38.3[a]	2.54	55.4	51.3	1.80
	Lactation	38.3[b]	29.8[a]	93.9[c]	3.20	52.8	55.2	3.10

[a,b,c]Means in a row without a common superscript letter differ ($P < 0.05$).

[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.

[3]X4 does, were supplemented on d 1 and 4, and X8 does were supplemented on d 1, 4, and 7 of the 8-d period.

Table 17. Effects of supplementation frequency, litter size, and production state on plasma NEFA (μEq/L) concentration in Angora does.

Day[1]	Production state[2]	Supplementation frequency[3]					Litter size		
		C	X1	X4	X8	SE	1	2	SE
Day 1	Gestation	697[b]	469[a]	450[a]	398[a]	63.5	411[a]	596[b]	44.9
	Lactation	638	767	878	811	75.1	837	710	66.8
Mean	Gestation	697[b]	469[a]	477[a]	444[a]	62.9	427[a]	616[b]	44.5
	Lactation	638	766	911	811	72.1	847	716	50.8

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Day (8-d periods): 1 = day of supplementation; mean = average of all samples (C and X1, sampled on d 1; X4, sampled on d 1 and 4; X8, sampled on d 1, 4, and 7).
[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.
[3]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 18. Effects of day of the period on plasma NEFA concentration (μEq/L) in Angora does supplemented every 4 or 8 days.

Supplementation frequency[1]	Production state[2]	Day of the period[3]				Litter size		
		1	4	7	SE	1	2	SE
X4	Gestation	450	641		66.5	559	532	56.0
	Lactation							
	Litter size 1	998	867		205			
	Litter size 2	705[a]	937[b]		181			
X8	Gestation	404	454	522	41.2	407[a]	667[b]	45.5
	Lactation	803	857	795	102.0	870	766	92.5

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).

[1]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

[2]The experiment consisted of 15 8-d periods; gestation: sampling in period 4; lactation: sampling in period 12.

[3]X4 does were supplemented on d 1 and 4, and X8 does were supplemented on d 1, 4, and 7 of the 8-d period.

Table 19. Effect of supplementation frequency, litter size, and production state on plasma serine concentration (µmol/mL) in Angora does.

Production		Supplementation frequency[1]				
state	Litter size	C	X1	X4	X8	SE
Gestation	1	144[a]	156[a]	361[b]	174[a]	46.9
	2	178	163	157	191	42.7
Lactation	1	144	157	264	172	24.1
	2	178	161	169	152	21.3

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).
[1]Supplementation frequency: C = no supplementation;
X1 = daily supplementation; X4 = supplementation every fourth day;
X8 = supplementation every eighth day.

Table 20. Effects of supplementation frequency, litter size, and production state on skin follicle growth characteristics in Angora does.

Day[1]	Supplementation frequency[2]					Litter size		
	C	X1	X4	X8	SE	1	2	SE
Apparent total follicle density, no./mm^2								
Day 0-57	23.9	24.4	26.5	24.2	1.32	25.8	23.6	0.929
Day 58-120	26.8	26.7	28.8	29.6	1.46	29.1	26.8	1.01
1° follicle activity, %								
Day 0-57	97.2	97.3	98.2	97.3	1.76	98.2	96.9	1.21
Day 58-120	95.5	99.5	98.7	99.8	1.47	99.3	97.4	1.03
2° follicle activity, %								
Day 0-57	98.6	98.8	98.7	93.8	3.25	99.0	96.0	2.15
Day 58-120	92	98.6	98.0	98.4	3.34	99.0	94.6	2.21
Primary:secondary ratio								
Day 0-57	6.95	7.04	7.30	6.84	0.300	7.27	6.79	0.212
Day 58-120	6.60	7.20	7.02	7.55	0.312	7.35	6.83	0.219

[1]Approximately one-half of the does had kidded on d 57.
[2]Supplementation frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Table 21. Effects of supplementation frequency, litter size, and production station on fiber growth characteristics in Angora does.

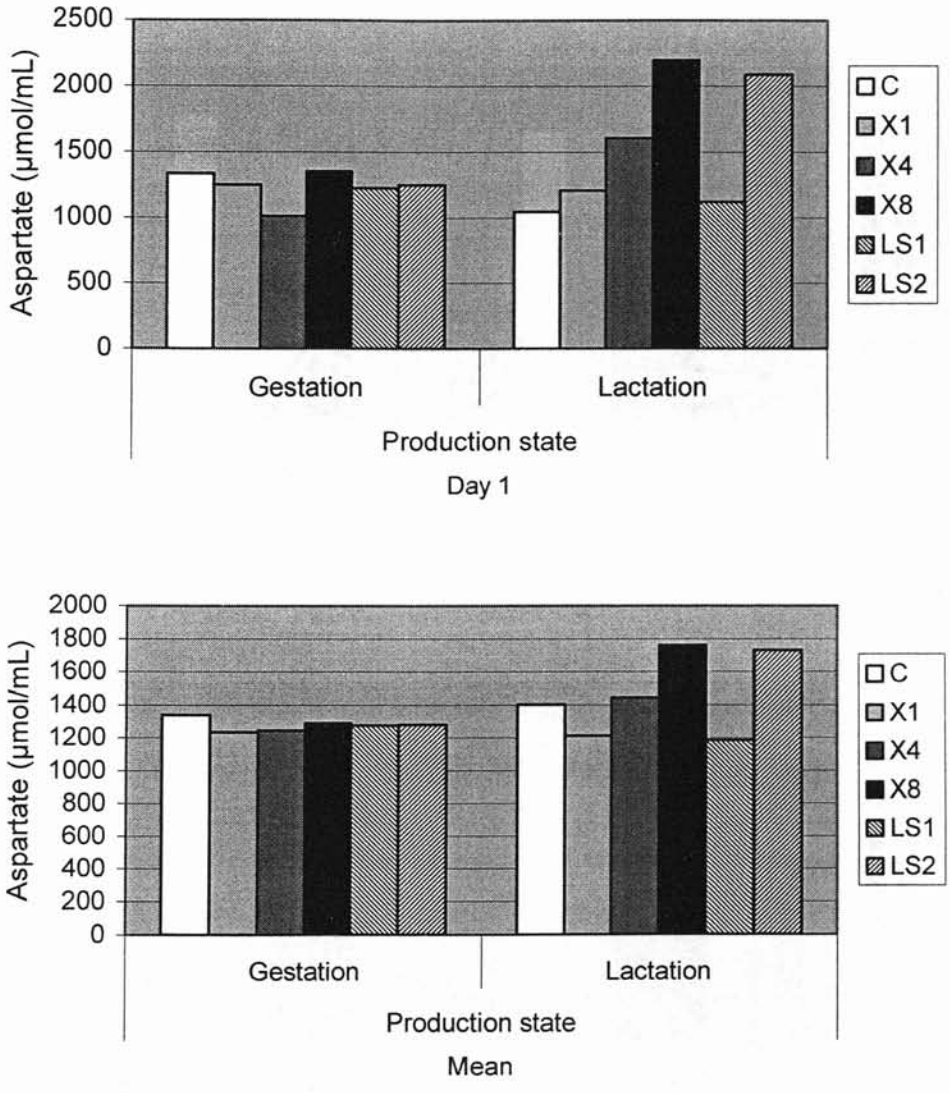
Day[1]	Supplementation frequency[2]				SE	Litter size		SE
	C	X1	X4	X8		1	2	
Clean fiber growth rate of patch, g/(100 cm^2·d)								
Day 0-57	0.065	0.061	0.060	0.070	0.007	0.062	0.066	0.006
Day 58-120	0.061[a]	0.089[b]	0.060[a]	0.079[ab]	0.009	0.070	0.074	0.006
Clean yield of patch, %								
Day 0-57	77.3	63.3	74.5	78.1	3.65	77.6	69.0	2.45
Day 58-120	82.5	82.8	74.5	78.1	6.00	80.8	81.0	4.20
Fiber diameter of patch, µm								
Day 0-57	31.3	32.0	25.7	31.5	5.55	31.5	28.7	3.89
Day 58-120	49.9	59.0	56.4	56.1	4.41	55.1	55.6	4.80
Clean staple strength of fleece, N/ktex	66.3	83.4	57.2	80.7	7.35	70.3	73.5	5.24

[a,b]Means in a row without a common superscript letter differ ($P < 0.05$).

[1]Approximately one-half of the does had kidded on d 57.

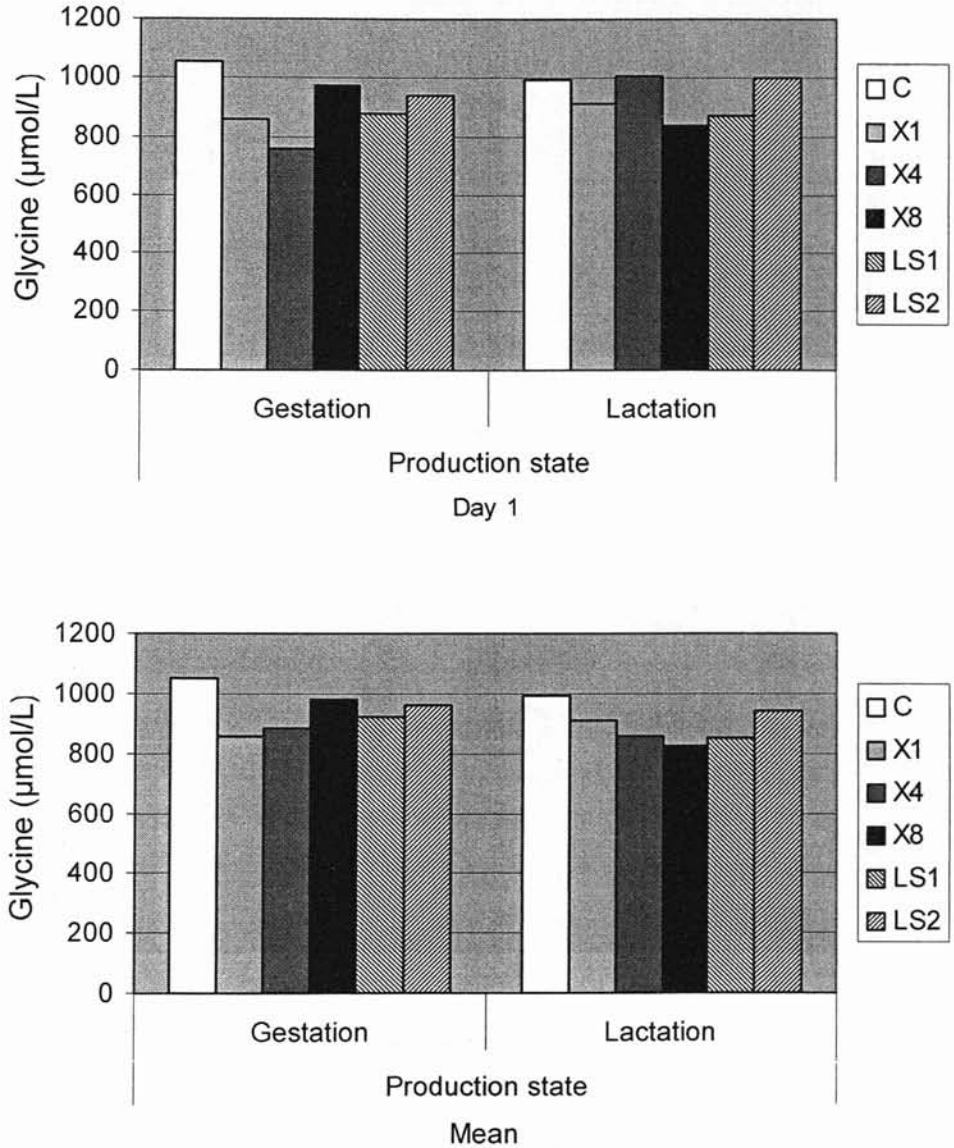
[2]Supplementation Frequency: C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day.

Figure 1. Effect of supplementation frequency, litter size, and production state on plasma aspartate concentration (μmol/mL) in Angora does.[1]



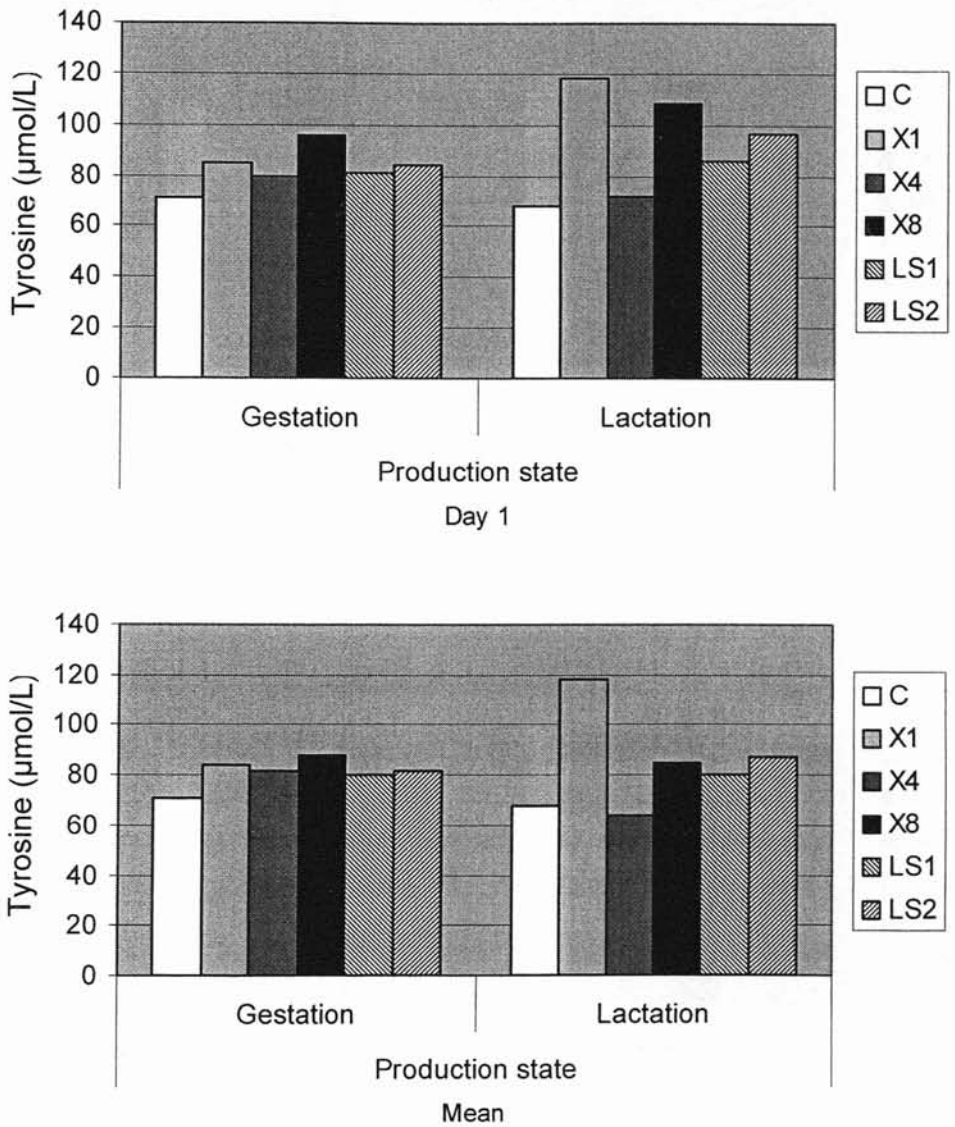
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 2. Effect of supplementation frequency, litter size, and production state on plasma glycine concentration (μmol/mL) in Angora does.[1]



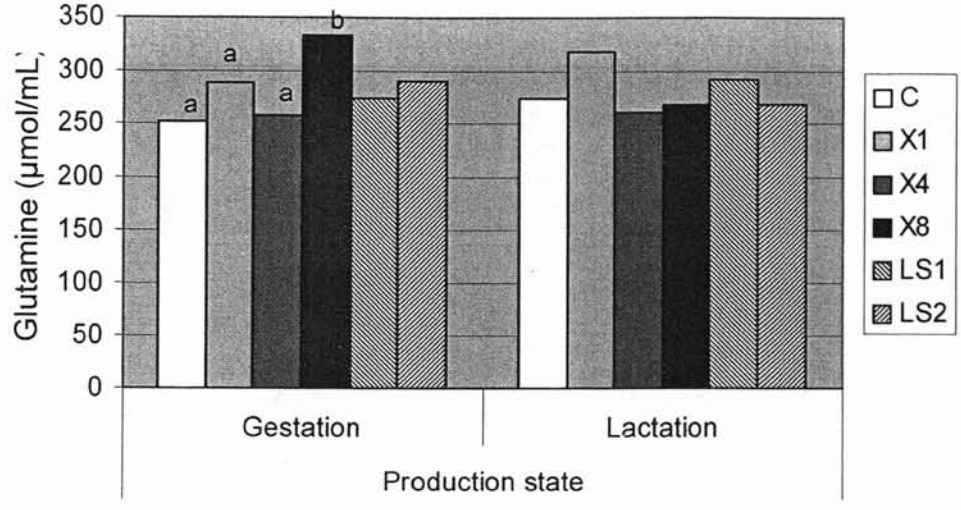
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 3. Effect of supplementation frequency, litter size, and production state on plasma tyrosine concentration (μmol/mL) in Angora does.[1]

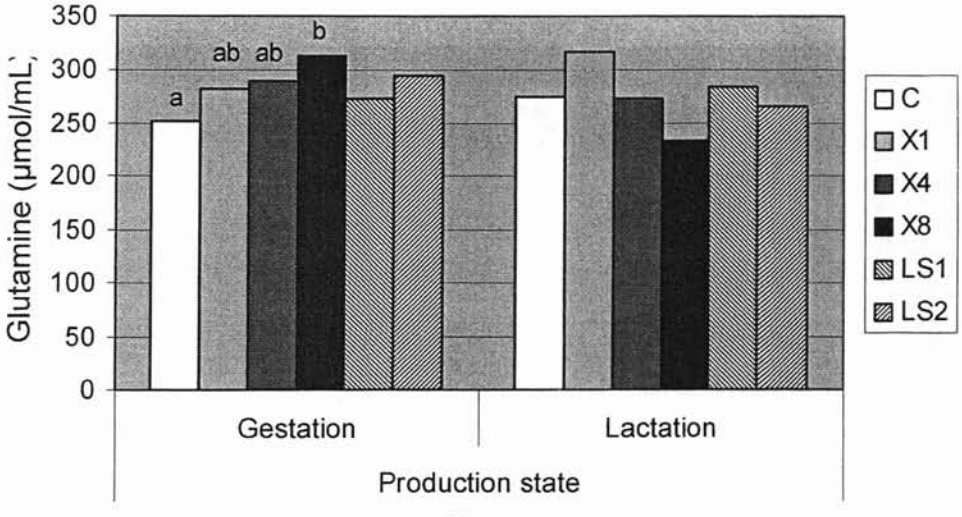


[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 4. Effect of supplementation frequency, litter size, and production state on plasma glutamine concentration (µmol/mL) in Angora does.[1]



Day 1

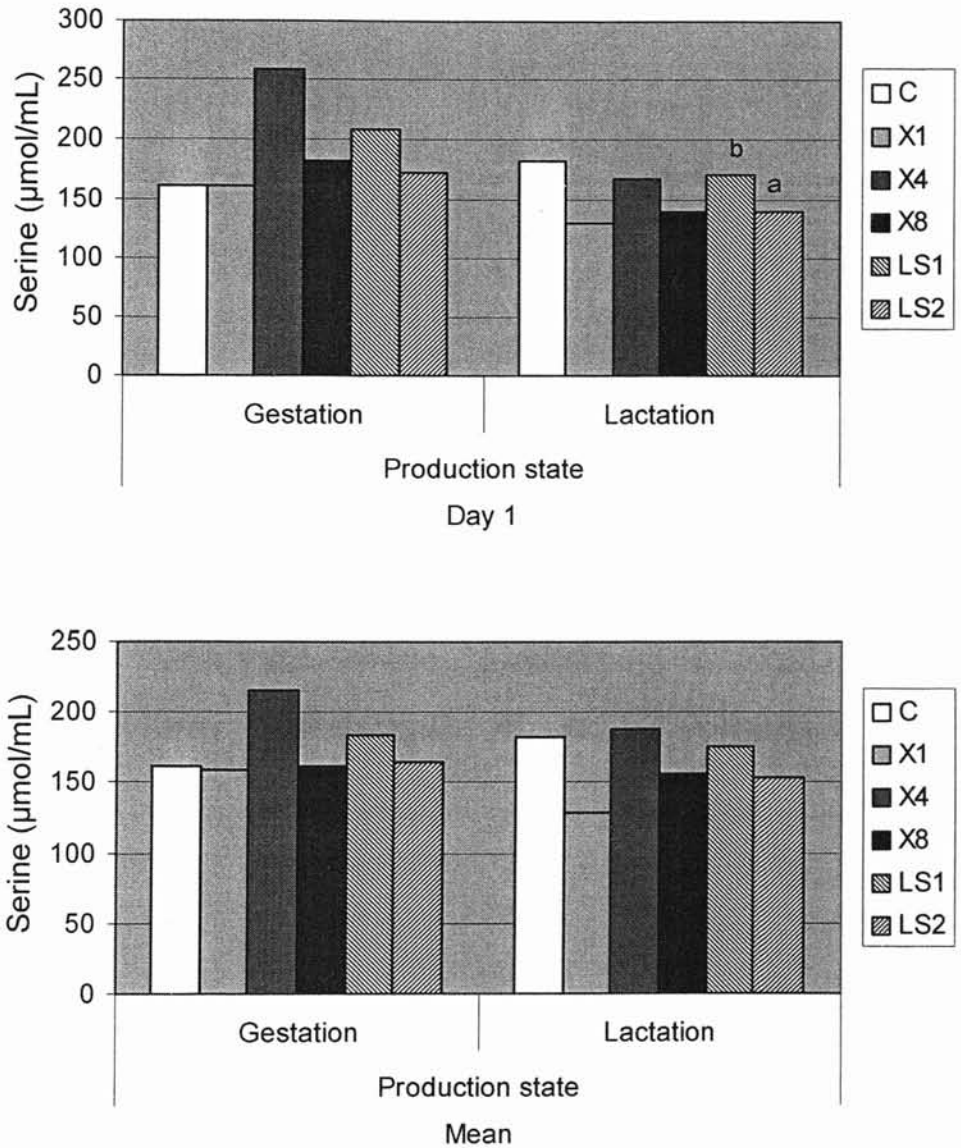


Mean

[a,b]Columns in a production state without a common superscript letter differ ($P < 0.05$).

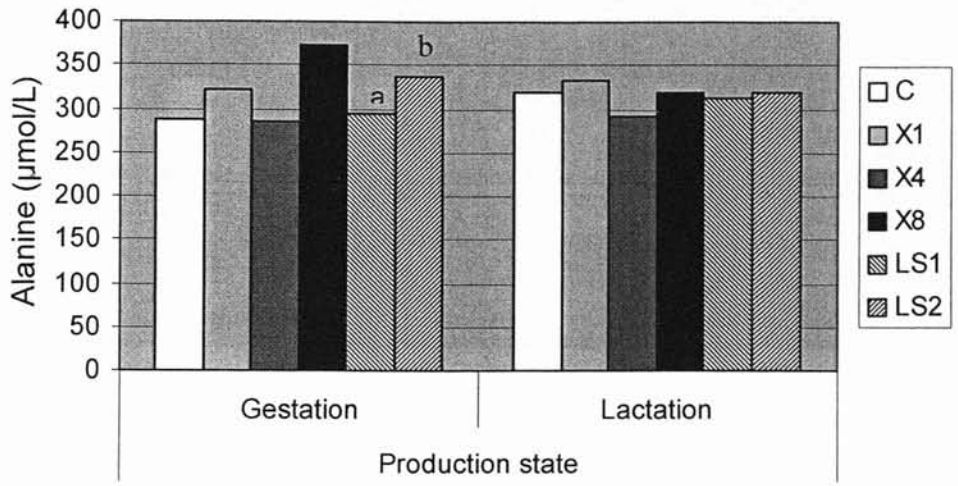
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

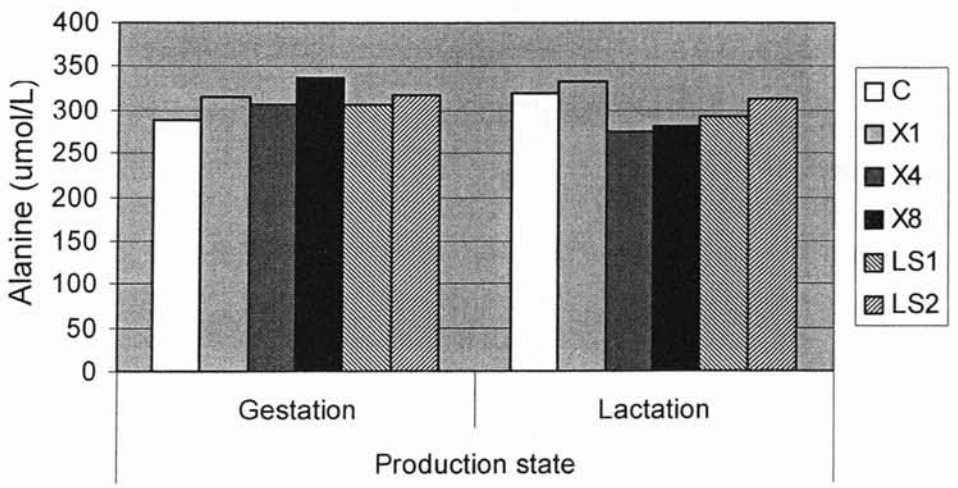
Figure 5. Effect of supplementation frequency, litter size, and production state on plasma serine concentration (µmol/mL) in Angora does.[1]



[a,b]Columns within a production state without a common superscript letter differ ($P < 0.05$).
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

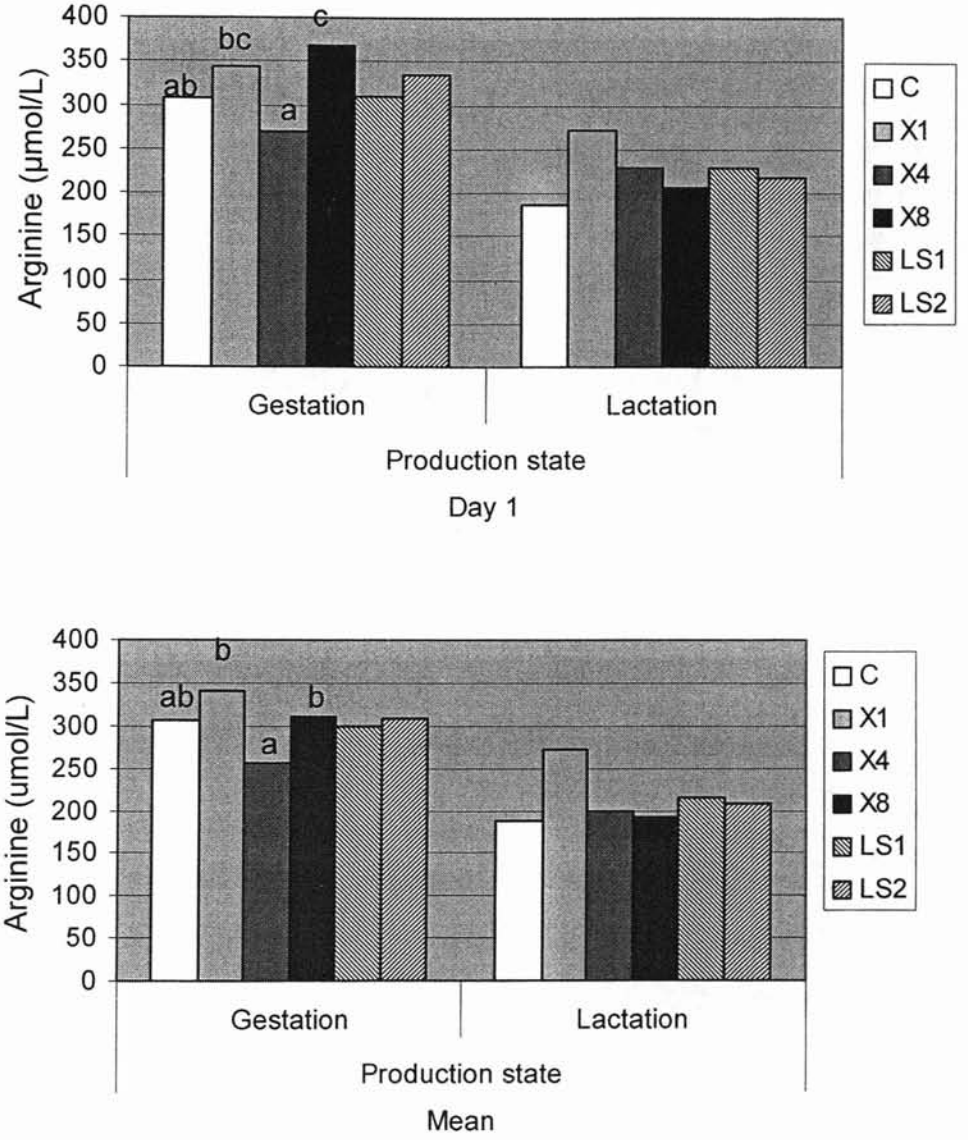
Figure 6. Effect of supplementation frequency, litter size, and production state on plasma alanine concentration (μmol/mL) in Angora does.[1]





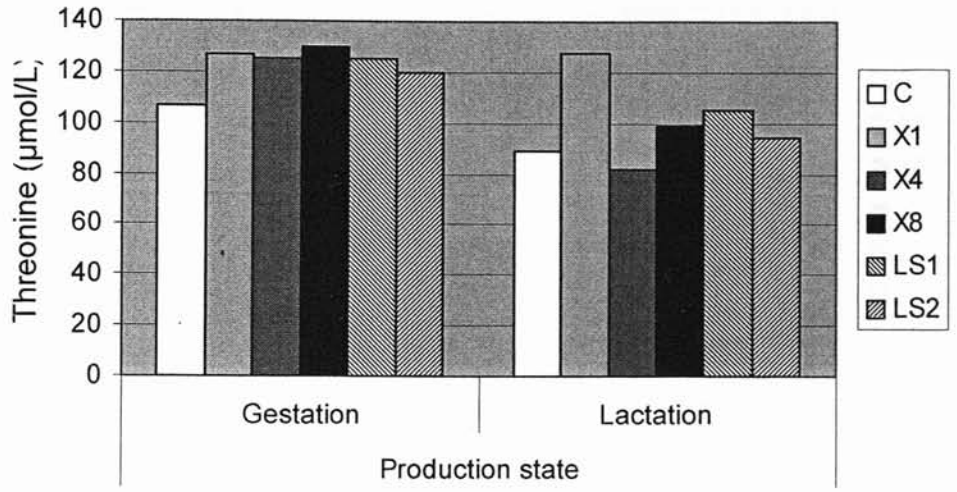
[a,b]Columns within a production state without a common superscript letter differ ($P < 0.05$).
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 7. Effect of supplementation frequency, litter size, and production state on plasma arginine concentration (μmol/mL) in Angora does.[1]

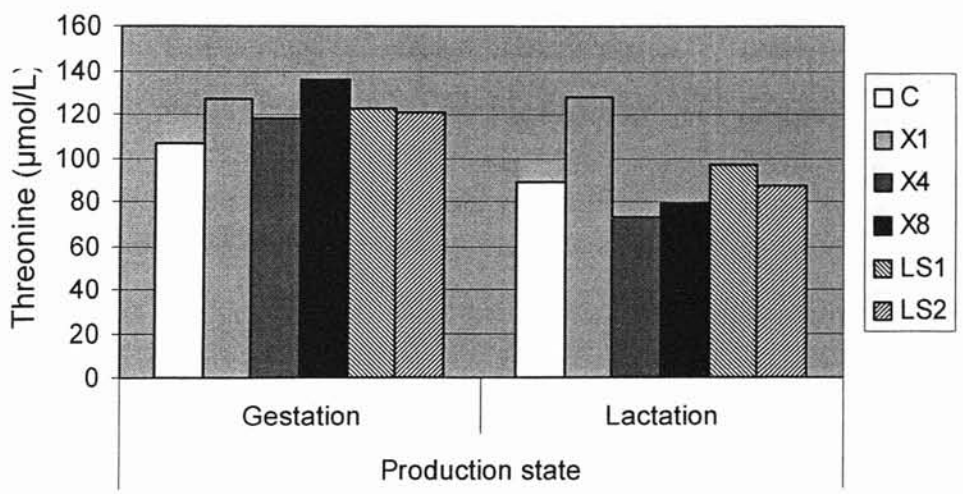


[a,b]Columns within a production state without a common superscript letter differ ($P < 0.05$).
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 8. Effect of supplementation frequency, litter size, and production state on plasma threonine concentration (μmol/mL) in Angora does.[1]



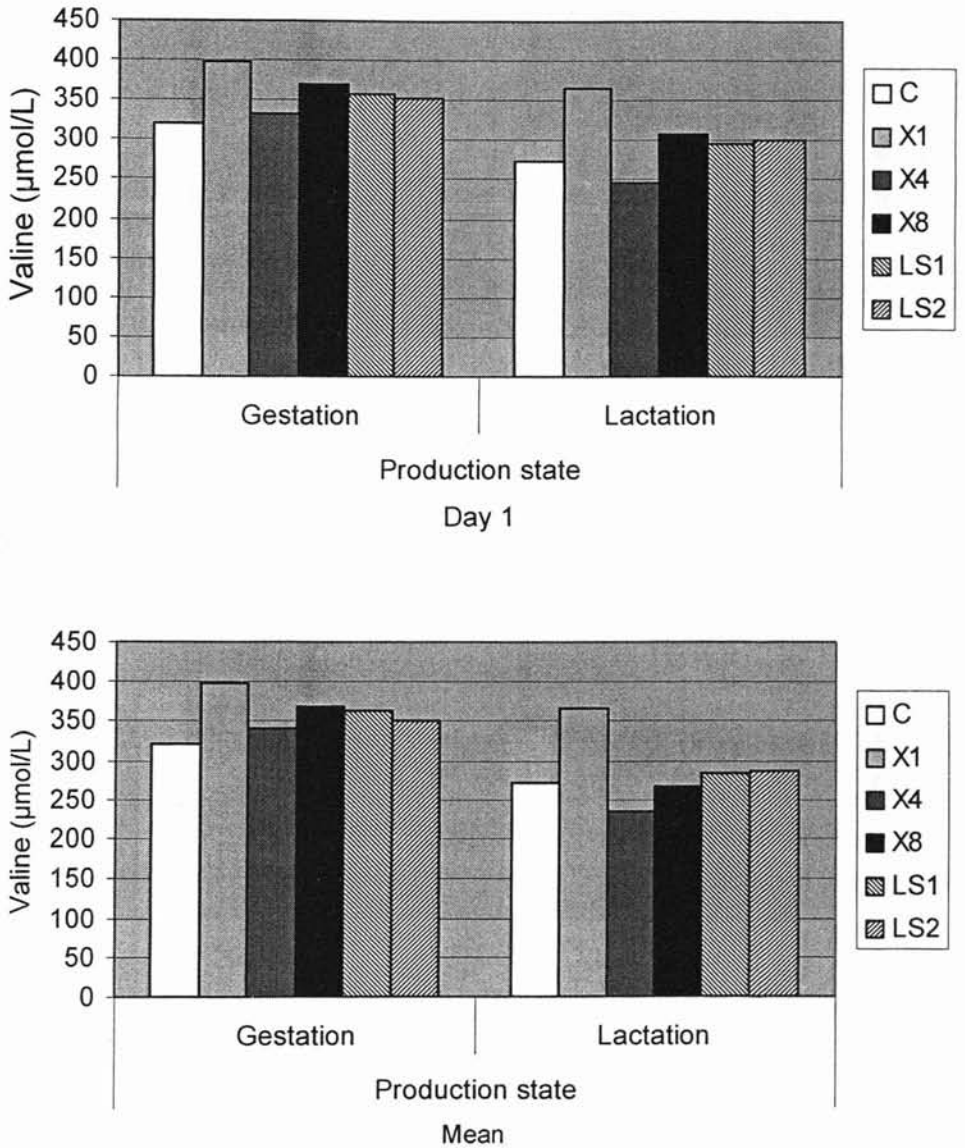
Day 1



Mean

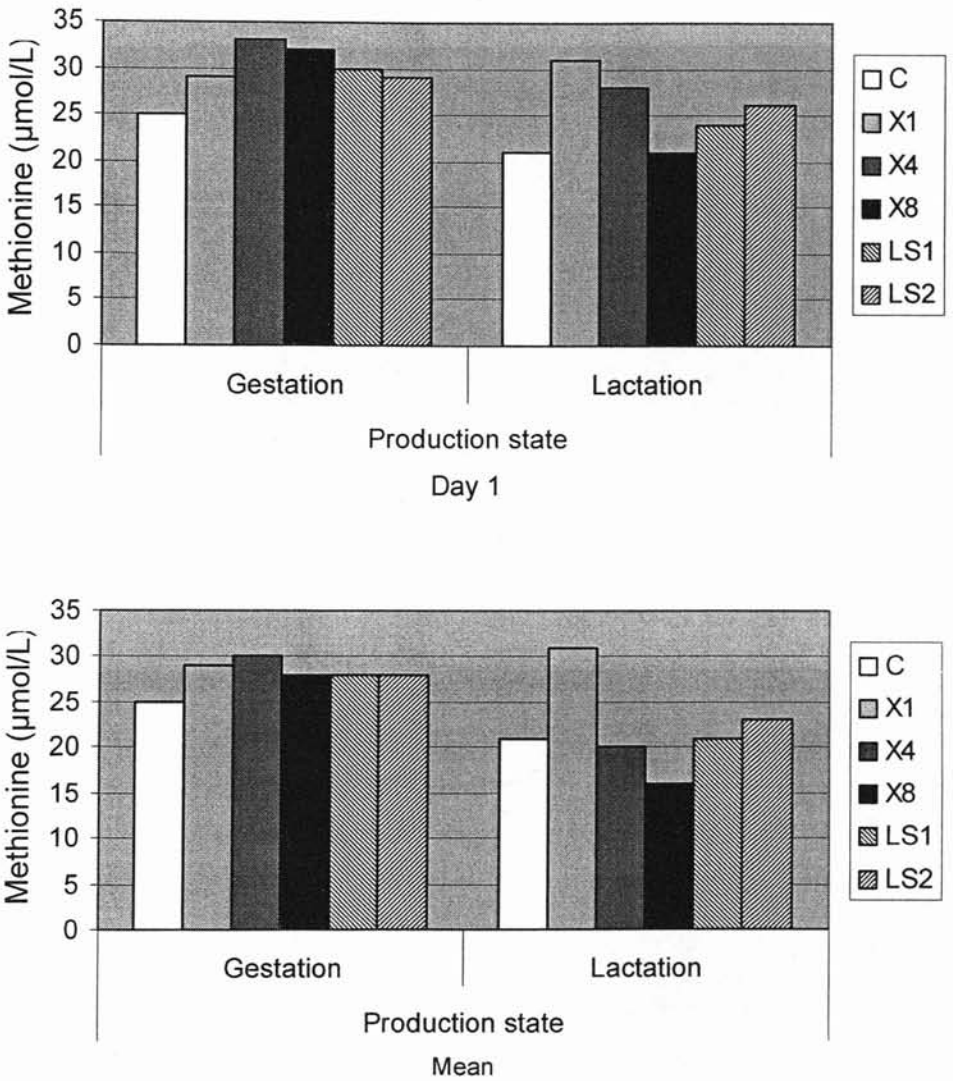
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 9. Effect of supplementation frequency, litter size, and production state on plasma valine concentration (μmol/mL) in Angora does.[1]



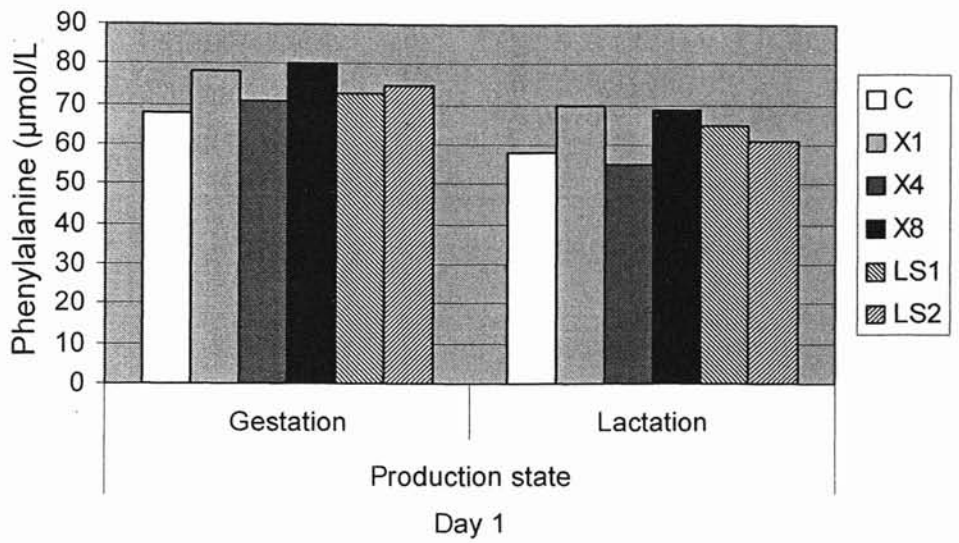
[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 10. Effect of supplementation frequency, litter size, and production state on plasma methionine concentration (μmol/mL) in Angora does.[1]

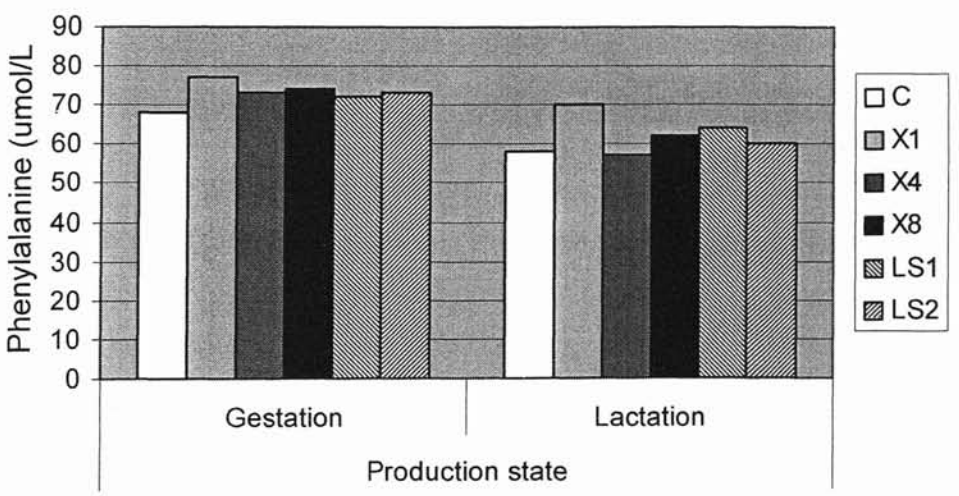


[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 11. Effect of supplementation frequency, litter size, and production state on plasma phenylalanine concentration (μmol/mL) in Angora does.[1]



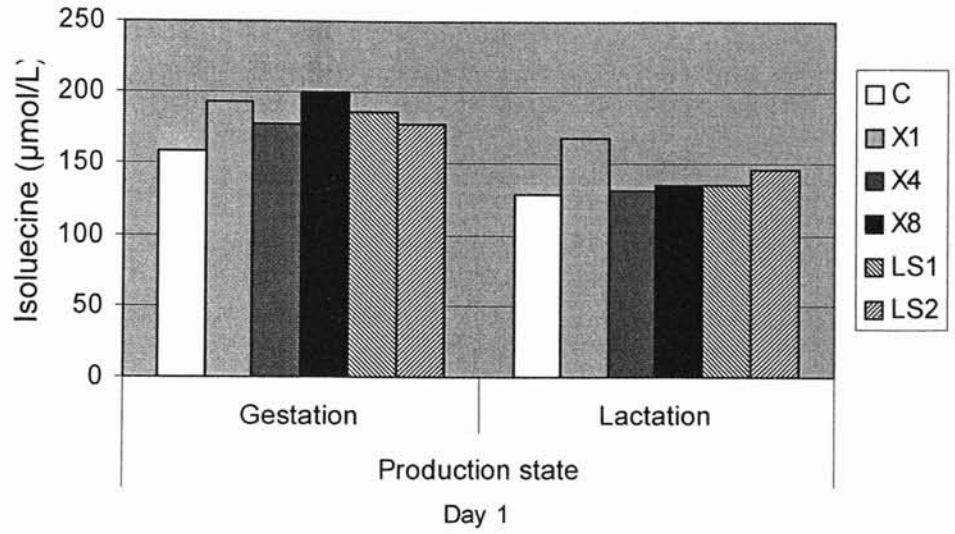
Day 1

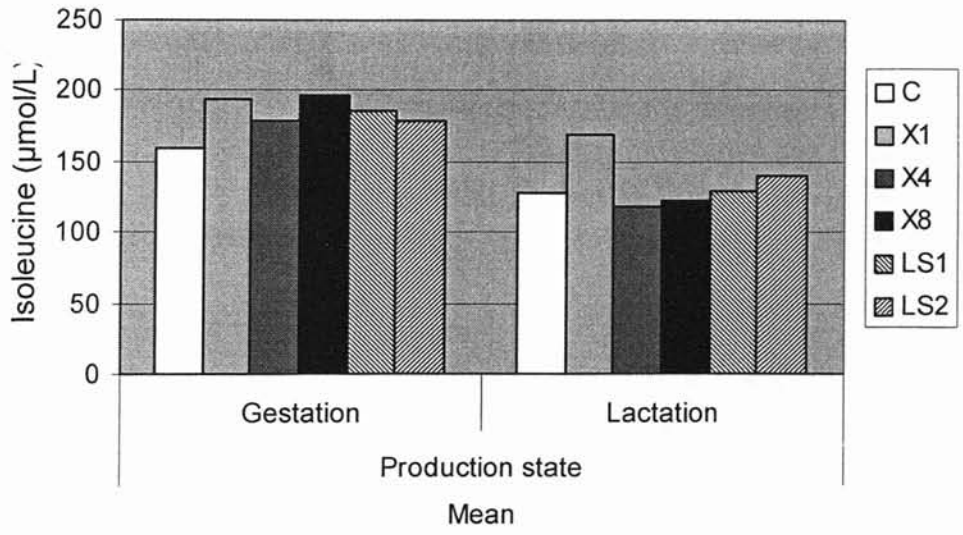


Mean

[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

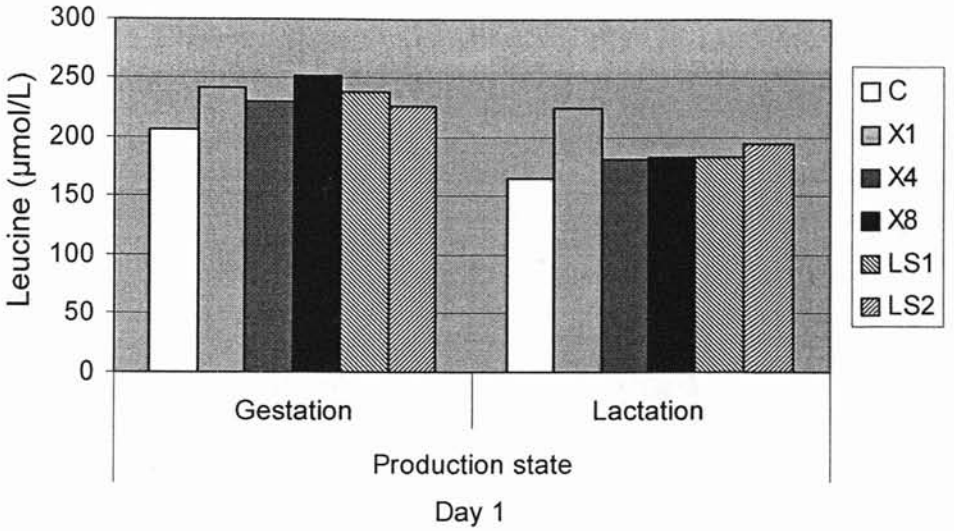
Figure 12. Effect of supplementation frequency, litter size, and production state on plasma isoleucine concentration (μmol/mL) in Angora does.[1]

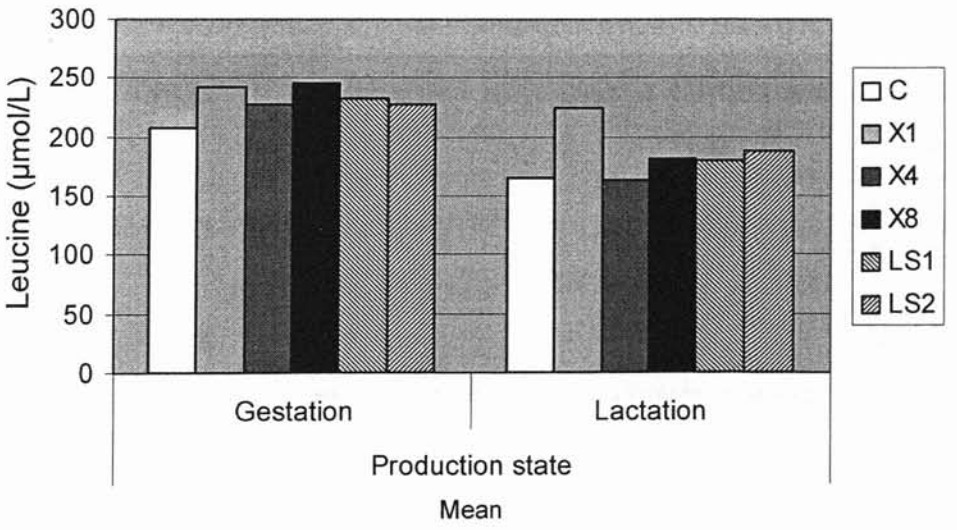




[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

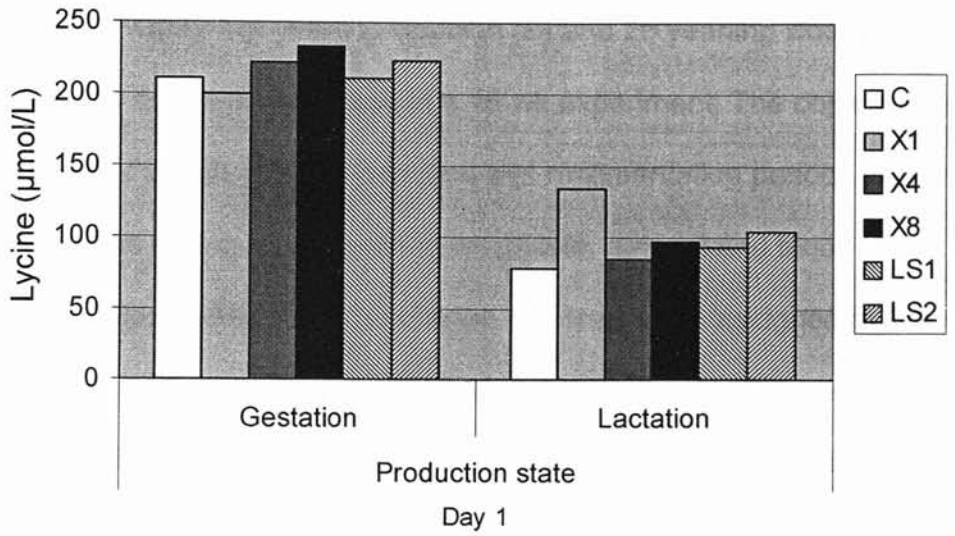
Figure 13. Effect of supplementation frequency, litter size, and production state on plasma leucine concentration (μmol/mL) in Angora does.[1]

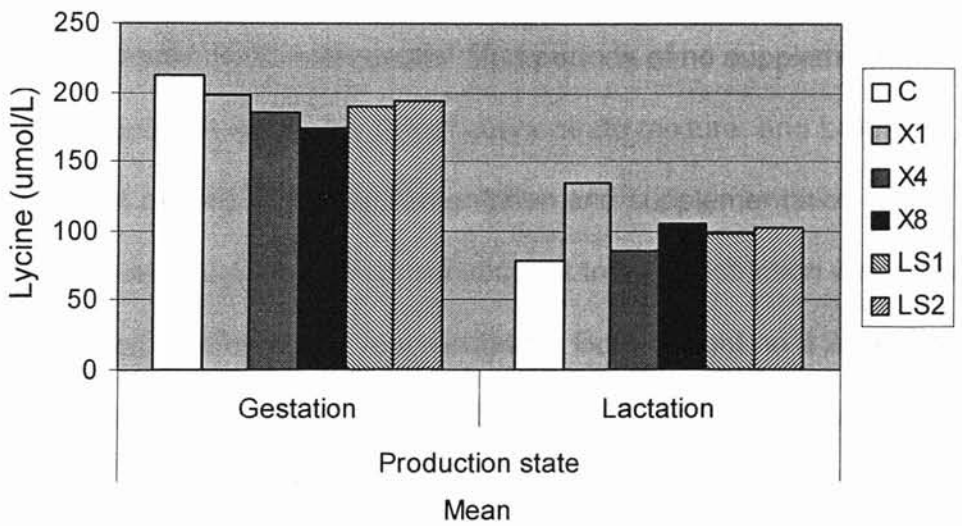




[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

Figure 14. Effect of supplementation frequency, litter size, and production state on plasma lysine concentration (μmol/mL) in Angora does.[1]





[1]C = no supplementation; X1 = daily supplementation; X4 = supplementation every fourth day; X8 = supplementation every eighth day; LS1 = does with single kids; LS2 = does with twins; 1 = day of supplementation within an 8-d period; mean = mean of samples taken on d 1 (all treatments), d 4 (X4 and X8), and d 7 (X8).

CHAPTER 4

EFFECTS OF LENGTH OF NUTRIENT RESTRICTION AND LEVEL OF REALIMENTATION ON GROWTH OF YEARLING SPANISH AND BOER X SPANISH DOELINGS

ABSTRACT: Twenty-five yearling Spanish (S) and 25 yearling Boer x Spanish (BS) crossbred doelings were used in a 16-wk experiment. The objective was to test the effect of length of feed restriction and realimentation periods and level of supplementation during realimentation on growth, ruminal and blood constituents, digestibilities, and N balance. Doelings were assigned to five groups: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; and L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture. Growth subsequent to feed restriction was influenced by length of feed restriction and realimentation. Body weight on d 28 was similar among treatments ($P > 0.05$). However, BW on d 56, 84, and 112 was affected by interactions between dietary treatment and genotype, with generally greater impact of dietary treatment on BW of BS doelings. Body weight at the end of the experiment was greater for BS vs S doelings, with no treatment differences among S doelings and lower BW for H-28, L-28, and L-56 vs C BS doelings. Forage intake by C doelings was fairly constant as the experiment progressed.

(e.g., dietary protein and energy concentrations), lengths of feed restriction and realimentation periods, and breed and age of the animal.

It has been speculated that some indigenous goats of Africa and the Middle East (e.g., black Bedouin) have lower energy requirements for maintenance relative to metabolic size compared with improved genotypes such as Saanen goats (Silanikove, 2000). Restricted feeding or low nutritional planes decrease the metabolic rate and maintenance energy requirement (Hornick et al., 2000). Silanikove (2000) postulated that goat genotypes may vary in the ability to minimize maintenance energy needs with low energy intake, although this area has not been extensively studied. Likewise, potential differences among genotypes in realimentation response have not been explored. In this regard, the number of Boer goats and Boer crossbreds being raised for meat in the US is increasing; however, numbers of the indigenous Spanish goat are still appreciable. Therefore, objectives of this experiment were to determine effects on growth performance by yearling Spanish and Boer x Spanish doelings of different lengths of nutrient restriction and level of realimentation.

Materials and Methods

Animals and Treatments

Twenty-five Spanish and 25 Boer x Spansh doelings (20.9 ± 0.55 and 27.0 ± 0.55 kg initial BW, respectively; approximately 12 mo of age) were used in a 16-week experiment. Doelings were placed in 50 individual pens (1.23 x 0.92 m) with an expanded metal floor, and adjusted to diets and experimental conditions for 2 weeks. All animals had free access to fresh water via nipple-waters and

were dewormed on January 26, and February 6, 2001 (5 cc Cydectin; Merck Ag Vet Division, Rahway, NJ) and vaccinated on February 9 and March 23, 2001 against *Clostridium perfringens* type C and D and tetanus toxoid (Colorado Serum Co., Denver, CO). Body weight was measured 1 week prior to the start of the experiment for allocation to treatments, and was measured again when it began. There were 10 doelings, 5 Spanish and 5 Boer x Spanish, allocated per treatment for similar mean BW and variation in BW among dietary treatment-genotype combinations.

The treatment arrangement was a 2 x 2 + 1 factorial, with a control, two daily levels of supplementation, and two lengths of periods with and without supplementation. Treatments are outlined in Table 1. All doelings consumed prairie hay (Table 2) offered at approximately 110% of intake on the preceding few days. Control doelings were supplemented daily with 0.75% BW of a concentrate mixture. The L-28 and H-28 treatments entailed no supplementation in weeks 1-4 and 9-12 and concentrate supplementation in weeks 5-8 and 13-16 at 0.75 and 1.5% BW (DM), respectively. The L-56 and H-56 doelings were not supplemented in weeks 1-8 but were given concentrate in weeks 9-16 at 0.75 and 1.5% BW (DM), respectively. Supplementation amounts were adjusted every 4 weeks based on BW. The supplemental concentrate mixture consisted (DM basis) of 20% ground corn, 20% ground oats, 20% wheat middlings, 20% soybean meal, 6.67% molasses, 5.33% fish meal, 4% blood meal, and 4% feather meal. Chemical composition is shown in Table 2.

Concentrate was fed first followed by hay. Concentrate consumption was complete on nearly all days. Hay refusals were collected and weighed daily before feeding concentrate. Because of the bulkiness of hay, as hay intake rose the number of times hay was offered each day was increased to two then three. A vitamin-mineral supplement, consisting of 23.3% dicalcium phosphate, 37% vitamin premix (2, 200, 000 IU/kg vitamin A; 1, 100, 000 IU/kg vitamin D; and 2, 200 IU/kg vitamin E), and 39.7% trace mineralized salt, was top-dressed on hay at a rate of 0.05% BW.

Sampling and Laboratory Analyses

BW and Feed. Body weight was measured weekly before feeding. Feedstuffs were grab sampled once weekly in weeks 1, 2, 4, 5, 6, 8, 9, 10, 12, 13, 14, and 16. In weeks 3, 7, 11, and 15 (digestibility and N balance period), feed and ort samples were collected daily and subsampled (10%) to form composite samples. All samples were refrigerated until analyses. Prairie hay and concentrate samples were analyzed for DM, ash (AOAC, 1990), CP (Technicon Instrument Co., Tarrytown, NY), NDF, ADF, ADIA (filter bag technique of ANKOM Technology Corp., Fairport, NY; Van Soest et al., 1991), and ADL (filter bag technique; ANKOM Technology Corp., Fairport, NY).

Blood and Ruminal Fluid. Blood was collected weekly after determining BW. Blood was collected using 22 gauge, 2.5-cm long needles by jugular venipuncture into two 10-mL vacutainers (Becton Dickinson, Franklin Lakes, NJ) containing heparin. Following collection, samples were chilled in ice for approximately 1 h and centrifuged (J-6B Centrifuge; Beckman Instruments, Inc.

Fullerton, CA) at 2,400 x *g* for 25 min at 4°C. After centrifuging, approximately 3 mL of plasma was withdrawn using a pipette and divided into two 1.5-mL micro centrifuge tubes (Fisher Scientific, Pittsburgh, PA) and stored below -20 °C until analyses. These samples were analyzed for NEFA with a commercial kit using an enzymatic colorimetric procedure (Wako Pure Chemical Industries, Richmond, VA) and urea N (Technicon Instrument Co., Tarrytown, NY).

During week 3, 7, 11, and 15, ruminal fluid samples were collected and analyzed for ammonia N by the phenol-hypochlorite colorimetric procedure of Broderick and Kang (1980) and VFA concentration was analyzed by gas chromatography as described by Lu et al. (1990).

Feces and Urine. Of the 50 animals in the experiment, 30 were used for digestibility and N balance determinations on the last 4 d of week 3, 7, 11, and 15. The individual pens were fitted with urine funnels placed below wire screens to collect urine. Feces was collected at the same time when feed refusals were sampled, with 10% aliquots taken to form a composite for each week of sampling. Urine was collected into containers with 20 mL of 20% (vol/vol) H_2SO_4. Because some fecal pellets were not caught on the wire screens, the composite sample was used for analysis of an internal, inert marker (i.e., acid detergent insoluble ash or ADIA; filter bag technique of ANKOM Technology Corp., Fairport, NY; Van Soest, et al., 1991) to estimate fecal output. Feces were analyzed for DM, ash (AOAC, 1990), N (Technicon Instrument Co., Tarrytown, NY), NDF, and ADF (filter bag technique; ANKOM Technology Corp., Fairport, NY). Urine was analyzed for N (Technicon Instrument Co., Tarrytown, NY).

Statistical Analysis

Data were analyzed using Proc Mixed of SAS (SAS Inst. Inc., Cary, NC. The model consisted of dietary treatment, genotype, and their interaction, with the random factor of animal. Body weight at the start of the experiment was used as a covariate for BW, ADG, and the ratio of ADG:DM intake. Data in each 28-d period was analyzed separately. Treatment means were separated by least significant difference when overall F-values were significant ($P < 0.05$). Main effect means for dietary treatment and breed were presented in tables when the dietary treatment x breed interaction was nonsignificant and when a significant difference in main effects existed.

Results

Animal Performance

Dry Matter Intake. Forage intake was generally greater for doelings when not supplemented with concentrate (Table 3 and Figure 1). During realimentation periods, 56-d restricted H supplemented BS doelings consumed less hay than C, whereas L supplemented doelings consumed similar amounts. These differences were, however, more evident in the first half of realimentation for doelings restricted for 56 d than in the second 28 d, and also in the first vs second realimentation period for 28-d restricted doelings. Total feed consumed was greater for the H vs L and C treatments during realimentation periods for the 56- and 28-d restricted BS doelings (Figure 2). Boer x Spanish doelings had greater total, concentrate, and hay DM intakes compared with S in all periods except for d 1-28.

Body Weight. Body weight on d 28 was similar among treatments ($P > 0.05$; Table 4). However, BW on d 56, 84, and 112 was affected by interactions between dietary treatment and genotype, with generally greater impact of dietary treatment on BW of Boer x Spanish (BS) doelings (Table 4 and Figure 3). One of the factors contributing to these interactions was BW of C goats relative to other treatments. Body weight of the BS doelings was greater ($P < 0.05$) or tended to be greater for C than for other treatments. Conversely, in all but one instance S C doelings had BW similar to other treatments. On d 56, BW was greater for BS C doelings vs H-56, L-56, and L-28 ($P < 0.05$) but was similar to H-28 ($P > 0.05$). Body weight for S doelings was lowest for L-56 on d 56, but similar among other treatments. On d 84, BW of BS C doelings was greatest among treatments ($P < 0.05$), although there were no treatment differences for S doelings. Body weight on d 112 was similar between C and H-56 and greater for C than for H-28, L-28, and L-56 ($P < 0.05$).

Average Daily Gain. There were no treatment differences in ADG between d 1 and 28 (Table 5). Average daily gain from d 29 to 56 was similar between the 28-d restricted and C groups; however, ADG was lowest among treatments for H-56 and L-56. On d 57 to 84, ADG for BS was lowest among treatments for H-28 and L-28 and similar among C, H-56, and H-28. For the S doelings, the only significant difference in ADG from d 57-84 was a greater value for H-56 vs C ($P < 0.05$). In the last 28 d of the experiment, ADG was lower for C than for L-28, H-56, and L-56 ($P < 0.05$). Figure 4 depicts the generally more consistent ADG among 28-d periods by C compared with other treatments.

Likewise, ADG for H-28 and L-28 varied with 28-d period less than did ADG for H-56 and L-56.

Average Daily Gain:DM Intake. Gain efficiency was not different between breeds or among treatments between d 1 and 28 (Table 6 and Figure 5). It was, however, greater from d 29 to 56 for C, H-28, and L-28 vs 56-d restricted doelings ($P < 0.05$). Gain efficiency on d 57-84 was similar among treatments for S doelings, but for BS it was lowest among treatments for H-28 and L-28 ($P < 0.05$). On d 85-112 ADG:DM intake was greater for H-56, L-56, and L-28 than for C ($P < 0.05$) and similar between H-28 and C.

Digestibility and Nitrogen Balance

Apparent total tract DM digestibility (g/d) on d 1 to 28 was similar among all BS dietary treatments, except H-28 that was lower and L-28 that was intermediate in comparison to C (Table 7). Between d 29 and 56, DM digestion (g/d) for BS was lower ($P < 0.05$) for the 56-d restriction treatments than for C and 28-d restriction treatments. For S doelings, DM digestion (g/d) was lower ($P < 0.05$) for C vs H-28, L-28, and H-56, but was similar for C vs L-56. There were no treatment and breed differences between d 57 to 84. Apparent total tract DM digestibility (%) was lowest for L-28 and highest for H-56 between d 85 and 112, with H-28 and L-56 intermediate in comparison with C.

Nitrogen digestion (g/d) was lower ($P < 0.05$) for doelings during restriction periods compared with C and was generally similar to values for C during realimentation periods (Table 8). However, there were no dietary treatment differences between d 85 and 112, although mean values were greater for BS vs

S doelings ($P < 0.05$). Nitrogen digestion (g/d) during the first half of the realimentation period for the 56-d restricted doelings was greater ($P < 0.05$) for the H vs L level of supplementation.

Organic matter digestibility (%) was similar among treatments on d 1 to 28 (Table 9). On d 29 to 56, OM digestion (%) was greater ($P < 0.05$) for C, H-28, and L-28 than for H-56 and L-56. Similarly, on d 57 to 84 OM digestion (%) was greater for C, H-56, and L-56 compared with H-28 and L-28 ($P < 0.05$). Between d 85 to 112, OM digestibility (%) was lower for H-28, L-28, and L-56 vs H-56 ($P < 0.05$), and intermediate ($P < 0.05$) for C.

Neutral detergent fiber digestibility (%) was not different among treatments in any of the four periods (Table 10). For the BS doelings NDF digestion (g/d) was lowest for H-28 between d 29 and 56, but for the S doelings it was lowest for C ($P < 0.05$).

As designed, N intake was greater when concentrate supplement was given and varied with level of supplementation (Table 11 and Figure 6). On d 18 to 21, urinary N excretion was greatest among treatments for C and lower for L-28, H-56, and L-56 than for H-28 ($P < 0.05$). Low urinary N excretion for L-28, H-56, and L-56 corresponds to high percentage N retention compared with C ($P < 0.05$). Urinary N excretion (g) and N retained (%) on d 46 to 49 were, however, similar among treatments. Percentage N retention on d 74 to 77 and 102 to 105 was similar among treatments as well.

Metabolite Status

Urea N. Urea N concentration on d 28 was, as expected, greatest among treatments for C ($P < 0.05$; Table 12). Similarly, on d 56 urea N concentration ranked ($P < 0.05$) H-28 > C and L-28 > H-56 and H-28. On d 84 and 99, BS doelings had higher urea N concentration than S. For BS doelings, urea N concentration was lowest among treatments for H-28 and L-28 and greater for H-56 vs C and L-56 ($P < 0.05$). For S, urea N concentration was greatest for H-56 ($P < 0.05$). Dietary treatment did not influence urea N level on d 99. Figure 7 depicts greater differences among sampling levels in urea N concentration in the second vs first half of the experiment, in general accordance with supplementation with concentrate (i.e., greater with than without) and concentrate level (greater for H vs L).

NEFA. There were no dietary treatment or breed differences in plasma NEFA concentration on d 28 or 99 (Table 12). In agreement with BW and ADG data, NEFA concentration was greater among treatments on d 56 for H-56 and L-28 ($P < 0.05$). Values on d 84 were consistently greater than on other days. Nonetheless, NEFA concentration was greater for H-28 and L-28 than for C, H-56, and L-56 ($P < 0.05$).

Ruminal Ammonia Nitrogen. During both 28- and 56-d restriction periods, ruminal ammonia-N levels for unsupplemented doelings were less ($P < 0.05$) than for C (Table 12 and Figure 8). When restriction treatment doelings were supplemented, ruminal ammonia N concentration was similar to C, except for a greater concentration for BS H-56 doelings on d 79 ($P < 0.05$). Figure 8

shows slightly greater ruminal ammonia N concentration in the first 28 d of realimentation compared with the second.

Discussion

Animal Performance

Overall growth subsequent to feed restriction was influenced by length of feed restriction and realimentation and breed type. Loss of BW during feed restriction, as for H-56 and L-56 primarily in the second 28 d of the 56-d restriction period, has been noted in many other reports. For example, Kamalzadeh et al. (1998) withdrew concentrate supplement from growing lambs and noted a decrease in BW. Hornick et al. (1998) noted that bulls fed diets low in energy and protein lost BW with increasing length of feed restriction. Sahlu et al. (1999) reported a decrease in BW of goats when feed intake was restricted.

Interactions between dietary treatment and genotype in ADG and BW suggest that growth of S doelings may be slightly less impacted by periodic changes in nutritional plane than that of BS doelings. In this regard, Silanikove (2000) suggested that goats indigenous to harsh environments are less susceptible to changes in quality and quantity of food supply and have lower nutrient requirements for maintenance vs improved genotypes. This difference may also be attributed to greater growth potential of BS doelings (Cameron et al., 2001), with generally greater ADG, ADG:DM intake, and total and hay intakes vs S.

Despite the lack of appreciable changes in BW for 28-d restricted S doelings compared with 56-d restriction treatments, there were tendencies for

greater ADG, total feed intake, and efficiency of gain during realimentation compared with C. In this regard Hornick et al. (2000) suggested that short-term underfeeding, without loss in BW, could induce adaptive mechanisms that allow nutrients to be spared for vital functions (Nozière et al., 2000).

Associated with decreased ADG during feed restriction was lower ADG:DM intake for H-28 and L-28 BS doelings on d 57 to 84 and for H-56 and L-56 of both breeds on d 29 to 56. A similar response was reported by Hornick et al. (1998) with cattle restricted for 411 d, with less efficient feed conversion compared with cattle restricted for 115 or 239 d. Average daily gain and feed efficiency of the 56-d restricted doelings increased at a faster rate during the first 4 wk of realimentation than the second; however, ADG was higher during the second than first 28 d of realimentation. Contrary to findings of this experiment, Yambayamba et al. (1996) reported that after 95 d restriction, heifers had greater ADG in the first half of realimentation vs the second.

Numerically greater forage intake for doelings when not supplemented with concentrate compared with C, and greater forage intake during restriction vs realimentation periods, are similar to findings of Goetsch and Aiken (1999) in which nonsupplemented sheep consumed more hay than when supplemented. Likewise, for 56-d restricted doelings supplementation at 1.5% BW resulted in lower hay intake compared with supplementation at 0.75% BW. This reflects substitution of supplement for hay, as also noted by Huston et al. (1999).

In summary of BW gain and ADG data, perhaps because of lower nutrient requirements growth and development of yearling S doelings appear less

susceptible to restricted nutritional planes than with BS doelings. Concomitantly, neither lengths of restriction and realimentation periods nor level of supplementation impacted S BW. Conversely, 28-d periods of restricted nutritional plane for BS either resulted in loss of, or no change in, BW that were not compensated for in subsequent 28-d realimentation periods regardless of supplementation level, suggesting a greater importance of the length of realimentation period. Because the magnitude of compensation is generally proportional to intensity of previous growth restriction (Horton and Holmes, 1978; Coleman and Evans, 1986; Hornick et al., 2000), this may have been due to the relatively short period of nutrient restriction.

Level of supplementation during realimentation influenced BW of BS with a limited nutritional plane for 56 d. The H level of supplementation for the subsequent 56 d was adequate for complete recovery of BW lost in the previous 56 d, with overall BW gain and final BW similar to that for C; whereas, the L supplementation level only allowed for final BW similar to that at the start of the experiment. Hence, the 56-d period was sufficient for expression of compensatory growth, but a relatively high level of supplementation was required to attain BW comparable to that of BS doelings continuously on a moderate to high nutritional plane.

These findings do not support the aforementioned postulate that periods of low nutritional plane markedly lower overall nutrient requirements or enhance efficiency of metabolism. Although, as evidenced by BW gain for S doelings, with little change in BW during periods of low nutritional plane, the severity of nutrient

restriction employed in this experiment by use of prairie hay was not great. Further experimentation with lower quality basal forage seems warranted.

Digestibility

Treatment differences in apparent total tract N digestion largely reflect differences in N intake due to supplementation, along with metabolic fecal N excretion that varies with DM intake. Similarly, OM digestion was generally greater with than without concentrate supplementation and for the H vs L level, because of greater potential digestion of concentrate than forage. Increased ruminal microbial degradation of forage responded to increased amino acid availability for concentrate supplementation than without and for H vs L supplementation, with similar results reported by Patil et al. (1996).

Nitrogen Balance

The 28- and 56-d restricted doelings exhibited a decrease in N excretion and an increase in percentage N retention during restriction periods (except for H-28) compared with C. Measures for H-56 and L-56 reflect an increase in percentage N retention and decrease in urinary N excretion with increasing duration of restriction. Subject to type and level of restriction, e.g., energy vs protein restriction (Drouillard et al., 1991) and level of feed intake (Sahlu et al., 1999), compensatory growth is characterized by a relatively greater increase in protein synthesis than degradation (Hornick et al., 2000), resulting in increased protein accretion and decreased nitrogen excretion as found in this experiment and with cattle in previous studies (Jones et al., 1990; Van Eenaeme et al., 1998).

Urea Nitrogen

Greater urea N levels for H-28 vs C and L-28 can be attributed to the high level of supplementation. Similar findings were reported by Hays et al. (1995) in which urea N levels in cattle increased linearly as dietary CP concentration in the realimentation diet increased.

Urea N levels for restriction treatments coincided with periods of restriction and concentrate supplementation. For H-56 and L-56, urea N levels were slightly greater after 28 vs 56 d of realimentation. Similar results were found by Yambayamba et al. (1996), with cattle restricted for 95 d having greater urea N levels than ones not restricted in the first half of realimentation but not later.

NEFA

Concentrations of NEFA greater during nutrient restriction than realimentation are indicative of lipolysis. Similarly, Yambayamba et al. (1996) found greater NEFA concentrations for cattle restricted for 95 d than during periods of realimentation.

Implications

The low nutritional plane imposed by consumption of prairie hay for 28 or 56 d was insufficient to markedly retard development of Spanish doelings. Hence, level of concentrate supplementation during realimentation had little or no effect on Spanish BW change. Yearling Spanish doelings may have lower nutrient requirements than Boer x Spanish doelings and may be less susceptible to periods of low nutritional planes. Realimentation periods of 28 d were inadequate for Boer x Spanish doelings to regain BW lost during 28-d nutrient

restriction periods, suggesting that longer periods of low nutritional plane and(or) realimentation are necessary for growth compensation. Nutrient restriction for 56 d caused an appreciable loss of BW by Boer x Spanish doelings. A high level of concentrate supplementation was necessary to achieve BW after the 56-d realimentation period similar to that of doelings continuously receiving a low level of supplementation, although the low level of concentrate was adequate for BW comparable to that at the beginning of the experiment. Therefore, it appears that meat goat doelings with moderate to high mature size and(or) growth potential, such as the Boer x Spanish, are prone to adverse effects on BW of periods of low nutritional plane. Lengthy nutrient restriction may require relatively long periods of high nutritional planes for appreciable compensatory growth.

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Table 2. Chemical composition (%) of feedstuffs fed to yearling Boer x Spanish and Spanish doelings.

Item	Hay	Concentrate
DM	92.2	89.5
	---------DM basis---------	
Ash	7.5	5.4
CP	5.3	24.1
NDF	64.9	25.9
ADF	39.1	8.13
ADL	9.19	4.41

Table 3. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on DM intake (g/d) by yearling Spanish and Boer x Spanish doelings.

Item	Day	Breed[2,3]	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
Forage intake	1-28	BS	444[b]	535[cd]	506[c]	550[d]	606[e]	12.1
		S	372[a]	597[e]	559[d]	603[e]	516[c]	
	29-56	BS	440[d]	315[b]	482[e]	556[fg]	536[f]	10.8
		S	278[a]	362[c]	390[c]	569[g]	538[f]	
	57-84	BS	569[d]	464[bc]	604[de]	449[b]	579[de]	14.0
		S	330[a]	617[e]	498[e]	333[a]	568[d]	
	85-112	BS	649[e]	541[c]	568[c]	610[d]	652[e]	13.1
		S	322[a]	660[e]	537[c]	432[b]	655[e]	
Concentrate intake	1-28	BS	233[c]	0[a]	0[a]	0[a]	0[a]	0.8
		S	183[b]	0[a]	0[a]	0[a]	0[a]	
	29-56	BS	234[c]	452[e]	228[c]	0[a]	0[a]	2.0
		S	184[b]	368[d]	186[b]	0[a]	0[a]	
	57-84	BS	235[d]	0[a]	0[a]	460[f]	226[c]	2.1
		S	185[b]	0[a]	0[a]	380[e]	181[d]	
	85-112	BS	239[b]	464[e]	237[b]	461[e]	240[b]	2.7
		S	190[a]	390[d]	194[a]	381[d]	190[a]	
Total DM intake	1-28	BS	677[f]	535[ab]	506[a]	550[b]	606[e]	12.0
		S	555[b]	597[c]	559[b]	603[d]	516[a]	
	29-56	BS	674[d]	767[f]	711[e]	556[bc]	536[b]	10.8
		S	462[a]	730[e]	576[c]	569[c]	538[b]	
	57-84	BS	803[f]	464[a]	604[d]	910[g]	805[f]	14.1
		S	514[c]	617[d]	498[bc]	713[e]	749[e]	

Item	Day	Breed[2,3]	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
	85-112	BS	888[e]	1,005[f]	804[c]	1068[g]	891[e]	13.7
		S	510[a]	1,051[g]	729[b]	811[cd]	843[d]	

[a,b,c,d,e,f,g]Means within a breed-dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]S = Spanish; BS = Boer x Spanish.

Table 4. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on BW (kg) of Spanish and Boer x Spanish doelings.

		Dietary treatment[1,2]					
Day	**Breed[2,3]**	**C**	**H-28**	**L-28**	**H-56**	**L-56**	**SE**
28	BS	26.2	24.8	23.8	25.0	23.9	0.57
	S	24.1	24.1	24.2	24.6	23.8	
56	BS	26.8^{e}	25.7^{de}	24.9^{cd}	23.2^{abc}	21.3^{a}	0.67
	S	24.2^{bcd}	24.4^{bcd}	24.0^{bcd}	23.3^{abc}	22.7^{ab}	
84	BS	29.4^{c}	25.6^{ab}	25.2^{ab}	26.9^{b}	24.5^{a}	0.79
	S	24.9^{ab}	25.3^{ab}	24.8^{ab}	25.1^{ab}	24.6^{ab}	
112	BS	31.3^{c}	27.9^{b}	27.5^{ab}	29.9^{bc}	27.5^{ab}	0.81
	S	25.2^{a}	25.9^{ab}	26.3^{ab}	26.9^{ab}	26.4^{ab}	

[a,b,c,d,e]Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction;

[3]S = Spanish; BS = Boer x Spanish.

Table 5. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on ADG (g) by yearling Spanish and Boer x Spanish doelings.

		Breed		Dietary treatment[1,2]					
Day	Breed[2,3]	Mean	SE	C	H-28	L-28	H-56	L-56	SE
1-28	BS			36	5	1	29	-23	16.0
	S			8	21	17	32	6	
29-56	BS			-5	0	24	-73	-74	15.5
	S			-8	-17	-3	-29	-57	
	Mean			-6^{b}	-9^{b}	11^{b}	-51^{a}	-65^{a}	10.9
57-84	BS			77^{cd}	1^{a}	2^{a}	100^{d}	104^{d}	15.1
	S			28^{ab}	29^{ab}	43^{abc}	48^{bc}	57^{bc}	
85-112	BS	85	5.8	62	77	83	103	99	12.7
	S	49		16	28	58	70	71	
	Mean			39^{a}	53^{ab}	71^{bc}	87^{c}	85^{c}	8.9

[a,b,c,d]Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]S = Spanish; BS = Boer x Spanish.

Table 6. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on ADG:DM intake (g/kg) in yearling Spanish and Boer x Spanish doelings.

		Breed		Dietary treatment[1,2]					
Day	Breed[2,3]	Mean	SE	C	Day	Breed[2,3]	Mean	SE	C
1-28	BS			47	5	-4	41	-38	26.5
	S			9	33	22	45	18	
29-56	BS			-7	-2	38	-146	-139	29.4
	S			-21	-26	-12	-49	-112	
	Mean			-14^{b}	-14^{b}	13^{b}	-98^{a}	-126^{a}	20.7
57-84	BS			98^{cd}	-11^{ab}	-20^{a}	112^{cd}	129^{d}	25.4
	S			63^{bc}	49^{abc}	90^{cd}	78^{cd}	76^{cd}	
85-112	BS	104	9.7	71	103	115	123	112	21.0
	S	70		36	24	83	122	88	
	Mean			54^{a}	63^{ab}	99^{bc}	122^{c}	100^{bc}	14.8

[a,b,c, d]Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]S = Spanish; BS = Boer x Spanish.

Table 7. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on apparent total tract DM digestibility in yearling Spanish and Boer x Spanish doelings.

Day[3]	Item	Breed[2,4]	Dietary treatment[1,2]					SE
			C	H-28	L-28	H-56	L-56	
1-28	Intake, g/d	BS	623^{bc}	461^{a}	554^{abc}	613^{bc}	670^{c}	53.3
		S	540^{abc}	673^{c}	605^{abc}	636^{c}	477^{ab}	
	Apparent digestion, %	BS	50.7	33.8	43.0	51.9	44.4	4.58
		S	52.1	49.4	45.4	48.8	55.7	
	Apparent digestion, g/d	BS	318^{b}	158^{a}	235^{ab}	322^{b}	296^{b}	38.2
		S	278^{b}	335^{b}	276^{b}	311^{b}	265^{b}	
29-56	Intake, g/d	BS	669^{bcd}	745^{cd}	729^{cd}	569^{b}	553^{b}	43.1
		S	411^{a}	784^{d}	632^{bc}	580^{b}	561^{b}	
	Apparent digestion, %	BS	71.3	70.5	74.6	66.8	62.0	2.38
		S	74.1	75.4	71.9	71.0	68.1	
		Mean	72.7^{b}	73.0^{b}	73.2^{b}	68.9^{ab}	65.0^{a}	1.69
	Apparent digestion, g/d	BS	477^{def}	527^{efg}	541^{fg}	380^{abc}	343^{ab}	28.9
		S	304^{a}	591^{g}	452^{cde}	411^{bcd}	381^{abc}	
57-84	Intake, g/d	BS	765	590	766	867	732	84.3
		S	474	785	589	680	766	
	Apparent digestion, %	BS	66.8	52.7	59.6	71.0	70.7	7.05
		S	71.1	62.4	56.8	76.6	66.2	
	Apparent digestion, g/d	BS	510	353	454	613	517	69.5
		S	336	487	337	520	500	

Day[3]	Item	Breed[2,4]	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
85-112	Intake, g/d	BS	831^{bc}	607^{ab}	727^{ab}	1059^{c}	843^{bc}	100.6
		S	477^{a}	1047^{c}	795^{bc}	805^{bc}	862^{bc}	
	Apparent digestion, %	BS	65.5	59.0	64.0	74.3	66.7	2.68
		S	68.5	66.5	58.9	69.6	62.0	
		Mean	67.0^{bc}	62.8^{ab}	61.4^{a}	72.0^{c}	64.4^{ab}	1.85
	Apparent digestion, g/d	BS	545^{abcd}	362^{ab}	475^{ab}	787^{d}	565^{bcd}	77.0
		S	328^{a}	698^{cd}	472^{ab}	566^{bcd}	536^{abc}	

^{a,b,c,d,e,f}Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]Days of measurement: d 1-28 = d 18-21; d 29-56 = d 46-49; d 57-84 = d 74-77; d 85-112 = d 102-105.

[4]S = Spanish; BS = Boer x Spanish.

Table 8. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on apparent total tract N digestibility in yearling Spanish and Boer x Spanish doelings.

			Breed		Dietary treatment[1,2]					
Day[3]	Item	Breed[2,4]	Mean	SE	C	H-28	L-28	H-56	L-56	SE
1-28	Intake, g/d	BS			17.2	9.6	6.0	6.8	7.6	1.74
		S			13.8	7.3	7.0	6.5	4.6	
		Mean			15.4^{b}	8.5^{a}	6.5^{a}	6.6^{a}	6.1^{a}	1.23
	Apparent digestion, %	BS			73.7	58.9	47.8	59.7	48.4	6.08
		S			73.7	54.9	60.1	52.7	56.9	
		Mean			73.7^{b}	56.9^{a}	54.0^{a}	56.2^{a}	52.6^{a}	4.34
	Apparent digestion, g/d	BS			12.7	6.7	2.9	4.0	3.7	1.68
		S			10.1	4.0	4.2	3.4	2.6	
		Mean			11.4^{b}	5.4^{a}	3.5^{a}	3.7^{a}	3.2^{a}	1.19
29-56	Intake, g/d	BS			13.8^{c}	16.8^{d}	13.7^{c}	3.4^{a}	3.1^{a}	0.72
		S			9.2^{b}	16.8^{d}	11.0^{b}	2.8^{a}	2.9^{a}	
	Apparent digestion, %	BS			82.4	77.7	82.2	25.6	42.3	13.09
		S			86.8	85.1	78.7	27.5	28.2	
		Mean			84.6^{b}	81.4^{b}	80.4^{b}	26.6^{a}	35.2^{a}	9.25
	Apparent digestion, g/d	BS			11.4	13.2	11.2	1.0	1.3	0.93
		S			8.0	14.3	8.6	0.7	0.9	
		Mean			9.7^{b}	13.8^{c}	9.9^{b}	0.8^{a}	1.1^{a}	0.66
57-84	Intake, g/d	BS	14.6	1.33	16.9	9.1	5.8	26.0	15.3	1.89
		S	10.9		11.1	6.9	5.3	16.5	14.7	
		Mean			14.0^{b}	8.0^{a}	5.5^{a}	21.3^{c}	15.0^{b}	1.33
	Apparent digestion, %	BS	67.1	4.27	78.0	58.6	30.7	88.1	79.8	9.53

Day[3]	Item	Breed[2,4]	Breed Mean	Breed SE	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
		S	52.8		82.9	21.6	20.5	84.5	54.5	
		Mean			80.5^{bc}	40.1^{a}	25.6^{a}	86.3^{c}	67.1^{b}	6.73
	Apparent digestion, g/d	BS	11.2	0.838	13.2	6.2	1.6	22.9	12.2	1.87
		S	6.86		9.2	1.7	1.2	14.3	8.0	
		Mean			11.2^{b}	4.0^{a}	1.4^{a}	18.6^{c}	10.1^{b}	1.32
85-112	Intake, g/d	BS			17.0^{c}	16.7^{c}	16.7^{c}	17.1^{c}	16.9^{c}	0.84
		S			10.4^{a}	17.3^{c}	15.1^{bc}	12.8^{b}	15.7^{c}	
	Apparent digestion, %	BS	73.7	1.68	76.8	79.8	69.7	69.0	73.4	3.74
		S	66.5		75.1	66.9	62.0	66.5	61.9	
	Apparent digestion, g/d	BS	12.4	0.36	13.1	13.2	11.6	11.8	12.4	0.80
		S	9.4		7.8	11.6	9.4	8.5	9.7	

[a,b,c]Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]Days of measurement: d 1-28 = d 18-21; d 29-56 = d 46-49; d 57-84 = d 74-77; d 85-112 = d 102-105.

[4]S = Spanish; BS = Boer x Spanish.

Table 9. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on apparent total tract OM digestibility in yearling Spanish and Boer x Spanish doelings.

Day[3]	Item	Breed[2,4]	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
1-28	Intake, g/d	BS	587^{bc}	435^{a}	523^{abc}	578^{bc}	633^{c}	50.2
		S	509^{abc}	635^{c}	571^{abc}	600^{c}	450^{ab}	
	Apparent digestion, %	BS	54.3	35.5	44.9	53.3	46	4.39
		S	55.0	51.2	46.9	50.7	57.1	
	Apparent digestion, g/d	BS	320^{b}	157^{a}	231^{ab}	312^{b}	290^{b}	35.6
		S	276^{b}	327^{b}	269^{b}	304^{b}	256^{b}	
29-56	Intake, g/d	BS	630^{bcde}	694^{de}	686^{cde}	576^{bc}	520^{b}	39.3
		S	387^{a}	738^{e}	594^{bcd}	546^{b}	528^{b}	
	Apparent digestion, %	BS	72.9	74.6	76.4	66.7	63.4	2.23
		S	76	77	73.2	72.3	69.3	
		Mean	74.5^{b}	75.8^{b}	74.8^{b}	69.5^{a}	66.4^{a}	1.58
	Apparent digestion, g/d	BS	459^{de}	519^{ef}	522^{ef}	383^{bcd}	330^{ab}	25.8
		S	293^{a}	569^{f}	433^{cd}	394^{bcd}	365^{abc}	
57-84	Intake, g/d	BS	705^{cd}	397^{a}	567^{abc}	838^{d}	674^{cd}	75.5
		S	438^{ab}	714^{cd}	536^{abc}	634^{bcd}	704^{cd}	
	Apparent digestion, %	BS	68.7	45.7	59.9	74.3	72.6	4.79
		S	72.9	64.1	58.3	78.3	68.5	
		Mean	70.8^{b}	54.9^{a}	59.1^{a}	76.3^{b}	70.6^{b}	3.39
	Apparent digestion, g/d	BS	484^{cde}	192^{a}	343^{bc}	621^{e}	489^{de}	51.5

Day[3]	Item	Breed[2,4]	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
		S	319^{ab}	455^{bcd}	315^{ab}	495de	476^{cde}	
85-112	Intake, g/d	BS	770^{bcd}	681^{b}	794^{bcd}	1029^{d}	781^{bcd}	82.2
		S	444^{a}	966^{cd}	735^{b}	752^{bc}	796^{bcd}	
	Apparent digestion, %	BS	67.5	63.5	69.0	75.8	68.8	2.49
		S	70.5	68.7	61.3	71.9	64.3	
		Mean	69.0^{ab}	66.1^{a}	65.1^{a}	73.8^{b}	66.6^{a}	1.76
	Apparent digestion, g/d	BS	520^{bc}	436^{ab}	547^{bc}	780^{d}	539^{bc}	66.4
		S	314^{a}	665^{cd}	454^{ab}	546^{bc}	513^{bc}	

^{a,b,c,d,e}Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment : C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Breed means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]Days of measurement: d 1-28 = d 18-21; d 29-56 = d 46-49; d 57-84 = d 74-77; d 85-112 = d 102-105.

[4]S = Spanish; BS = Boer x Spanish.

Table 10. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on total tract NDF digestibility in yearling Spanish and Boer x Spanish doelings.

Day[3]	Item	Breed[2,4]	Dietary treatment[1,2] C	H-28	L-28	H-56	L-56	SE
1-28	Intake, g/d	BS	316^{abc}	313^{ab}	376^{abcd}	416^{cd}	455^{d}	36.2
		S	285^{a}	457^{d}	411^{cd}	432^{d}	324^{abc}	
	Digestion, %	BS	34.7	22.6	37.0	44.0	37.2	6.04
		S	34.3	43.9	36.8	43.1	59.6	
	Digestion, g/d	BS	112	73	136	187	168	27.1
		S	95	203	152	186	160	
29-56	Intake, g/d	BS	326^{ab}	267^{b}	364^{c}	396^{c}	358^{c}	27.7
		S	183a	338^{bc}	325^{bc}	375^{c}	363^{c}	
	Digestion, %	BS	58.7	47.7	65.3	59.6	56.1	4.55
		S	62.2	62.0	60.5	66.6	63.0	
	Digestion, g/d	BS	191^{b}	131^{a}	237^{b}	235^{b}	200^{b}	18.5
		S	113^{a}	210^{b}	194^{b}	249^{b}	228^{b}	
57-84	Intake, g/d	BS	347^{bc}	251^{ab}	357^{bc}	334^{bc}	334^{bc}	46.6
		S	201^{a}	450^{c}	338^{bc}	239^{ab}	370^{bc}	
	Digestion, %	BS	48.2	27.3	50.0	50.1	56.2	6.66
		S	51.9	54.4	43.5	56.0	51.9	
	Digestion, g/d	BS	167^{abcd}	77^{a}	183^{bcd}	168^{bcd}	187^{cd}	28.9
		S	104^{ab}	243^{d}	149^{abc}	133^{abc}	189^{cd}	

Day[3]	Item	Breed[2,4]	Dietary treatment[1,2]					SE
			C	H-28	L-28	H-56	L-56	
85-112	Intake, g/d	BS	373^{bc}	319^{ab}	386^{bc}	408^{bc}	337^{ab}	49.0
		S	206^{a}	508^{c}	369^{b}	299^{ab}	408^{bc}	
	Digestion, %	BS	47.9	38.0	50.1	56.5	49.1	6.00
		S	51.6	53.3	44.4	45.5	45.9	
	Digestion, g/d	BS	179^{abc}	127^{ab}	195^{abc}	231^{bc}	166^{abc}	40.3
		S	107^{a}	274^{a}	170^{abc}	141^{ab}	191^{abc}	

^{a,b,c,d,e,f,g}Means within a breed dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment : C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction;

[3]Days of measurement: d 1-28 = d 18-21; d 29-56 = d 46-49; d 57-84 = d 74-77; d 85-112 = d 102-105.

[4]S = Spanish; BS = Boer x Spanish.

Table 11. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on nitrogen retention by yearling Spanish and Boer x Spanish doelings.

			Breed		Diet treatment[1,2]					
Day	Item	Breed[2,3]	Mean	SE	C	H-28	L-28	H-56	L-56	SE
18-21	N intake, g	BS			17.2	9.6	6.0	6.8	7.6	2.09
		S			14.1	7.3	7.1	6.5	4.8	
		Mean			15.7^{b}	8.5^{a}	6.6^{a}	6.6^{a}	6.2^{a}	1.49
	N in feces, g	BS			4.5	2.9	3.2	2.7	3.9	0.49
		S			4.1	3.3	2.9	3.1	2.2	
	N in urine, g	BS			15.4	5.3	3.4	1.0	0.7	1.89
		S			17.2	11.7	3.2	1.2	0.3	
		Mean			16.3^{c}	8.5^{b}	3.3^{a}	1.1^{a}	0.5^{a}	1.34
	N retained, %	BS			-18.6	-21.0	-11.9	45.9	39.2	26.45
		S			-51.0	-107.0	14.3	34.7	48.4	
		Mean			-34.8^{ab}	-64.0^{a}	1.2^{bc}	40.3^{c}	43.8^{c}	18.81
	N retained, g/d	BS			-2.7	1.4	-0.6	3.1	3.0	3.04
		S			-7.2	-7.7	1.0	2.2	2.3	
46-49	N intake, g	BS			13.8^{c}	16.8^{d}	13.7^{c}	3.03^{a}	3.1^{a}	0.72
		S			9.2^{b}	16.7^{d}	11.0^{b}	2.8^{a}	2.9^{a}	
	N in feces, g	BS			2.4	3.6	2.5	2.5	1.8	0.50
		S			1.2	2.5	2.4	2.1	1.9	
	N in urine, g	BS			0.4	3.6	0.1	0.3	3.4	2.15
		S			0.5	1.7	1.0	0.4	2.9	
	N retained, %	BS			79.1	56.8	81.1	6.3	-62.5	21.86
		S			81.7	74.2	69.9	14.1	-72.7	
		Mean			80.4^{c}	65.5^{c}	75.5^{c}	10.2^{b}	-67.6^{a}	15.49
	N retained, g/d	BS			11.0	9.6	11.1	0.2	-2.1	1.64
		S			7.5	12.6	7.6	0.3	-2.0	

Day	Item	Breed[2,3]	Breed Mean	Breed SE	Diet treatment[1,2] C	H-28	L-28	H-56	L-56	SE
		Mean			9.2[b]	11.1[b]	9.3[b]	0.3[a]	-2.0[a]	1.16
74-77	N intake, g	SB			16.9	9.1	5.8	26.0	15.3	1.98
		S			11.1	6.9	5.3	16.5	14.7	
		Mean			14.0[b]	8.0[a]	5.5[a]	21.3[c]	15.0[b]	1.43
	N in feces, g	SB			3.8	2.9	4.2	3.1	3.0	0.97
		S			1.9	5.5	4.1	2.3	6.7	
	N in urine, g	SB			7.1	1.1	0.4	10.5	7.8	1.89
		S			7.4	1.3	0.7	5.5	1.9	
		Mean			7.3[c]	1.2[ab]	0.5[a]	8.0[c]	4.9[bc]	1.34
	N retained, %	SB			34.9	37.7	22.0	47.3	28.4	18.60
		S			18.8	-0.1	6.2	52.6	41.5	
	N retained, g/d	BS			6.0	5.1	1.2	12.4	4.4	2.54
		S			1.8	0.1	0.5	8.7	6.1	
102-105	N intake, g	SB			16.6[c]	16.7[c]	16.8[c]	17.1[c]	16.9[a]	0.95
		S			10.4[a]	17.3[c]	15.1[bc]	12.8[a]	15.6[c]	
	N in feces, g	SB			3.8	3.4	5.1	5.3	4.5	0.76
		S			2.6	5.8	5.7	4.2	5.9	
	N in urine, g	SB			5.3	2.9	0.9	4.4	4.0	5.67
		S			3.8	3.1	2.2	1.8	1.0	
	N retained, %	SB			45.3	63.9	63.9	43.7	49.3	6.93
		S			38.6	49.4	47.4	37.2	55.4	
	N retained, g/d	BS	8.9	0.55	7.5	10.3	10.6	7.5	8.4	1.20
		S	6.6		4.0	8.5	7.2	4.5	8.7	
		Mean			5.8[a]	9.4[b]	8.9[b]	6.0[a]	8.5[ab]	0.86

[a,b,c]Means within a breed-dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment : C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential

28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]S = Spanish; BS = Boer x Spanish.

Table 12. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on concentrations of urea N, NEFA in serum, and ruminal fluid ammonia N in yearling Spanish and Boer x Spanish doelings.

			Breed		Dietary treatment[1,2]					
Item	Day	Breed[2,3]	Mean	SE	C	H-28	L-28	H-56	L-56	SE
Urea N,	28	BS			23	13	12	8	12	2.1
mg/dL		S			18	13	13	13	17	
		Mean			21[b]	13[a]	12[a]	11[a]	14[a]	0.9
	56	BS			15	26	16	5	8	1.3
		S			15	21	15	5	5	
		Mean			15[b]	23[c]	16[b]	5[a]	6[a]	1.1
	84	BS			12[cd]	8[ab]	6[a]	16[e]	13[d]	0.9
		S			9[b]	8[ab]	8[ab]	15[de]	9[bc]	
	99	BS	11		13	12	11	11	12	1.0
		S	10	0.4	10	11	10	10	9	
NEFA, µEq/L	28	BS			424	487	498	476	424	37.0
		S			422	517	454	467	413	
	56	BS			163	184	311	588	505	79.4
		S			229	163	262	563	441	
		Mean			196[a]	174[a]	287[a]	575[b]	473[b]	55.7
	84	BS			497	1070	955	543	688	131.0
		S			737	1068	877	609	468	
		Mean			617[a]	1069[b]	916[b]	576[a]	578[a]	91.5
	99	BS			155	196	220	173	160	27.6
		S			236	199	194	219	156	

Item	Day	Breed[2,3]	Breed		Diet treatment[1,2]					
			Mean	SE	C	H-28	L-28	H-56	L-56	SE
Ruminal	23	BS			14.6	1.7	2.5	1.5	5.8	1.71
ammonia		S			13.9	4.2	3.4	2.7	2.6	
N, mg/dL		Mean			14.2[b]	2.9[a]	3.0[a]	2.1[a]	4.2[a]	1.21
	51	BS			15.5	19.5	13.8	0.3	1.6	2.15
		S			17.0	20.5	14.9	1.0	0.8	
		Mean			16.2[b]	20.0[c]	14.3[b]	0.6[a]	1.2[a]	1.52
	79	BS			25.8[b]	0.7[a]	1.6[a]	40.4[c]	22.0[b]	3.11
		S			28.3[b]	1.2[a]	1.5[a]	22.5[b]	28.6[b]	
	10 7	BS			18.4	19.8	18.3	14.9	16.1	2.06
		S			18.8	21.7	16.3	16.6	17.4	

[a,b,c,d,e]Means within a breed-dietary treatment grouping without a common superscript letter differ ($P < 0.05$).

[1]Dietary treatment: C = control, daily supplementation with 0.75% BW of concentrate mixture; H-28 = sequential 28-d periods of no supplementation and daily supplementation with 1.50% BW of concentrate mixture; L-28 = sequential 28-d periods of no supplementation and daily supplementation with 0.75% BW of concentrate mixture; H-56 = sequential 56-d periods of no supplementation and daily supplementation with 1.5% BW of concentrate mixture; L-56 = sequential 56-d periods of no supplementation and supplementation with 0.75% BW of concentrate mixture.

[2]Main effect means are presented when significantly different ($P < 0.05$) and with a nonsignificant dietary treatment x breed interaction.

[3]S = Spanish; BS = Boer x Spanish.

Figure 1. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on forage intake by yearling Spanish and Boer x Spanish doelings.

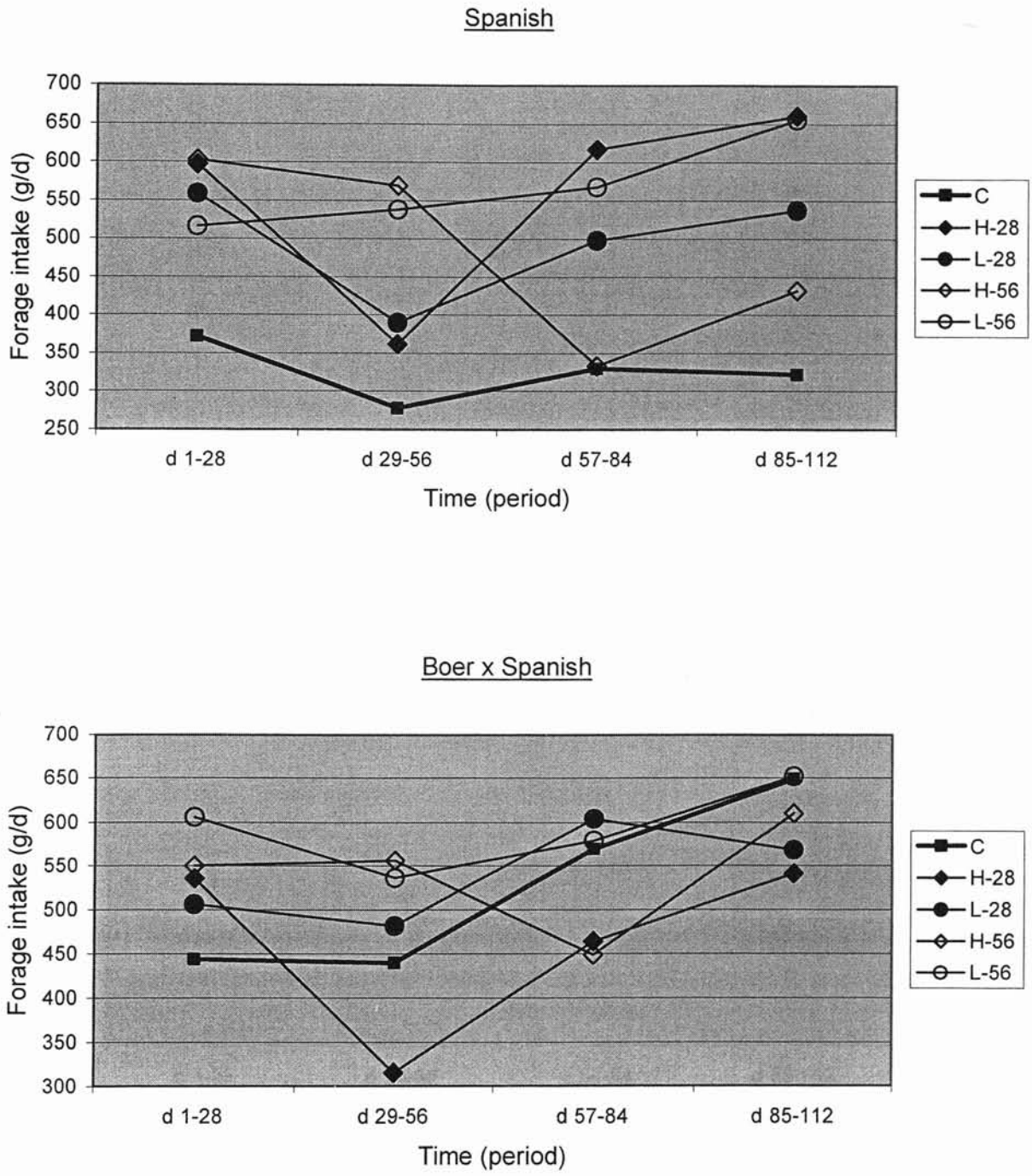


Figure 2. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on total intake by yearling Spanish and Boer x Spanish doelings.

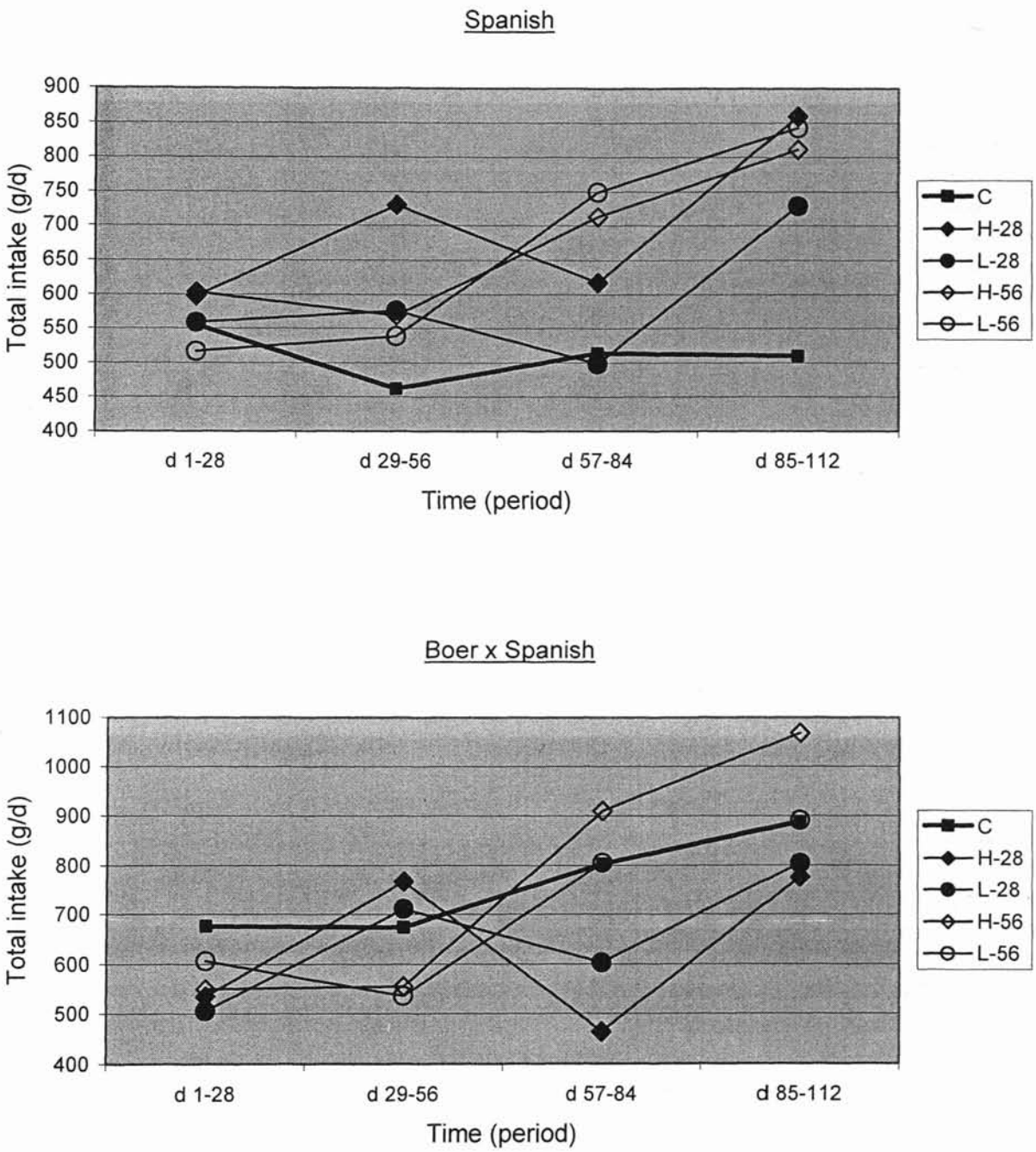
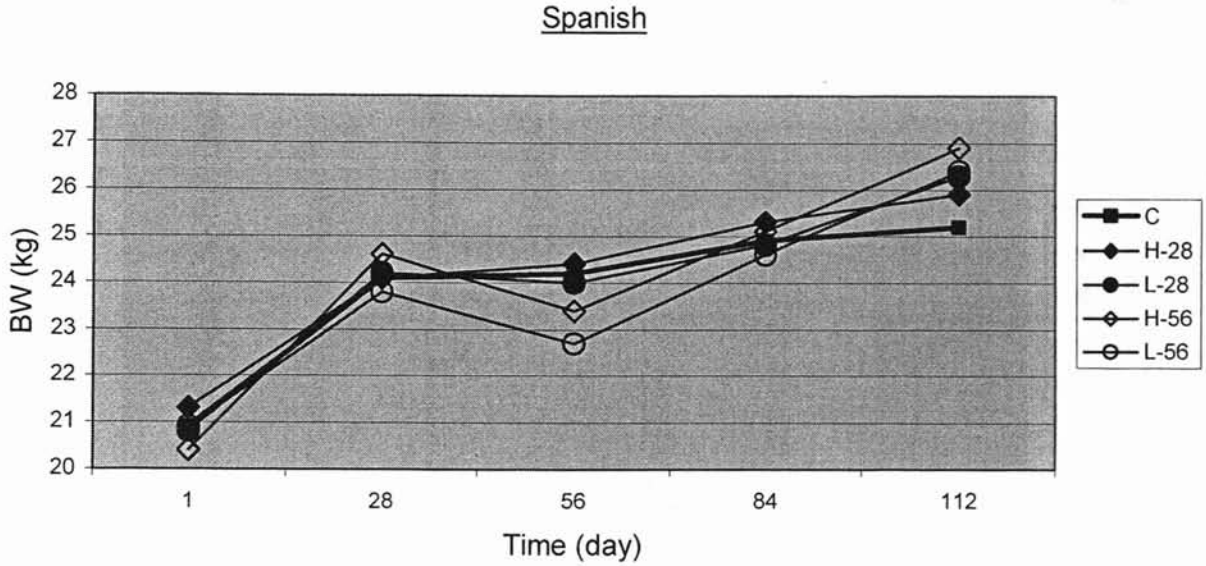


Figure 3. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on BW of yearling Spanish and Boer x Spanish doelings.



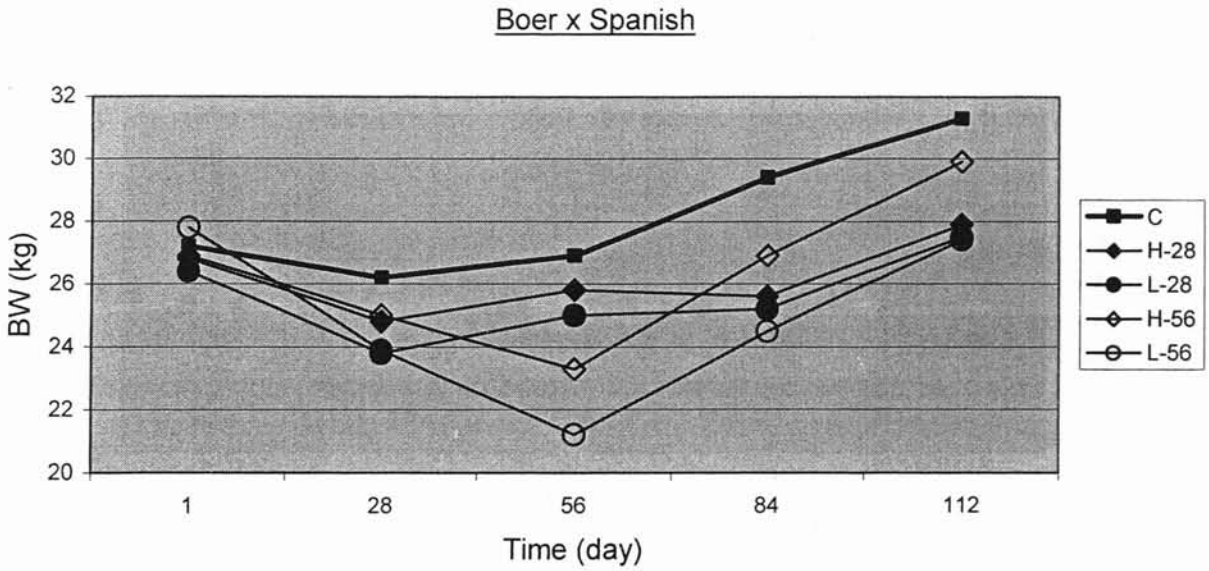
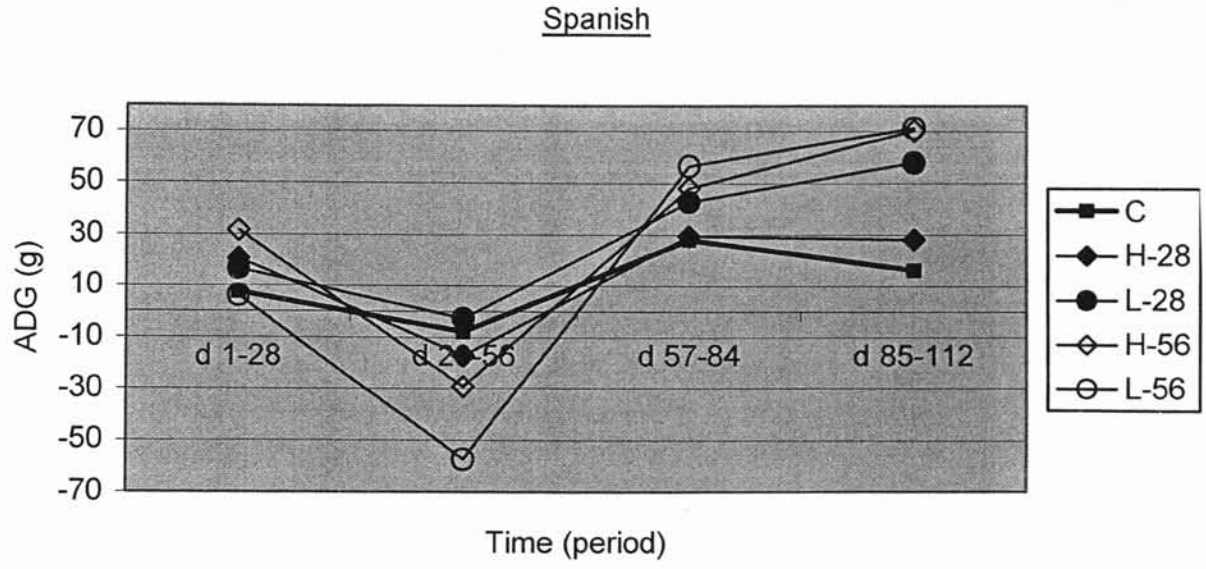


Figure 4. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on ADG by yearling Spanish and Boer x Spanish doelings.



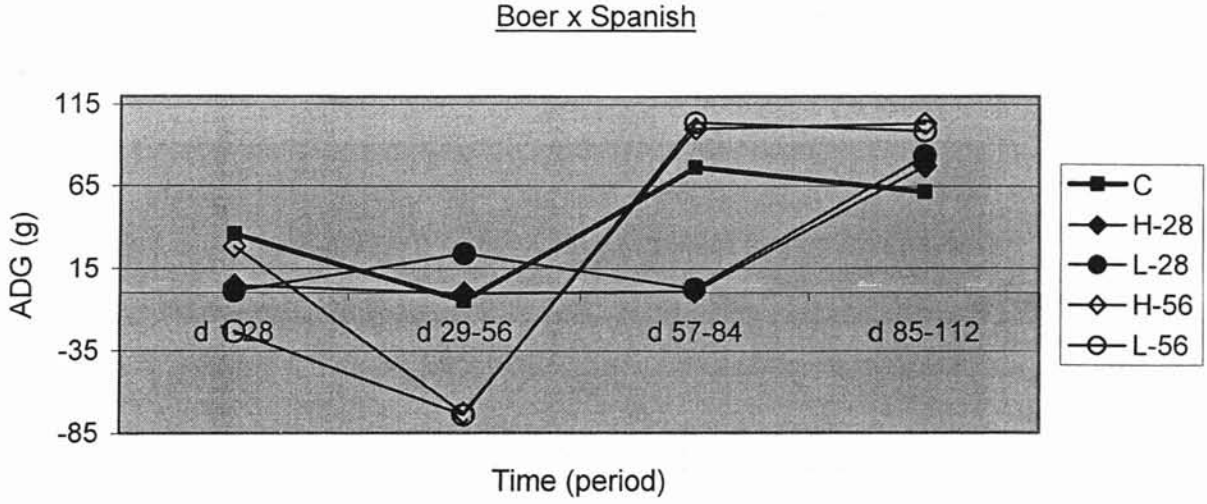
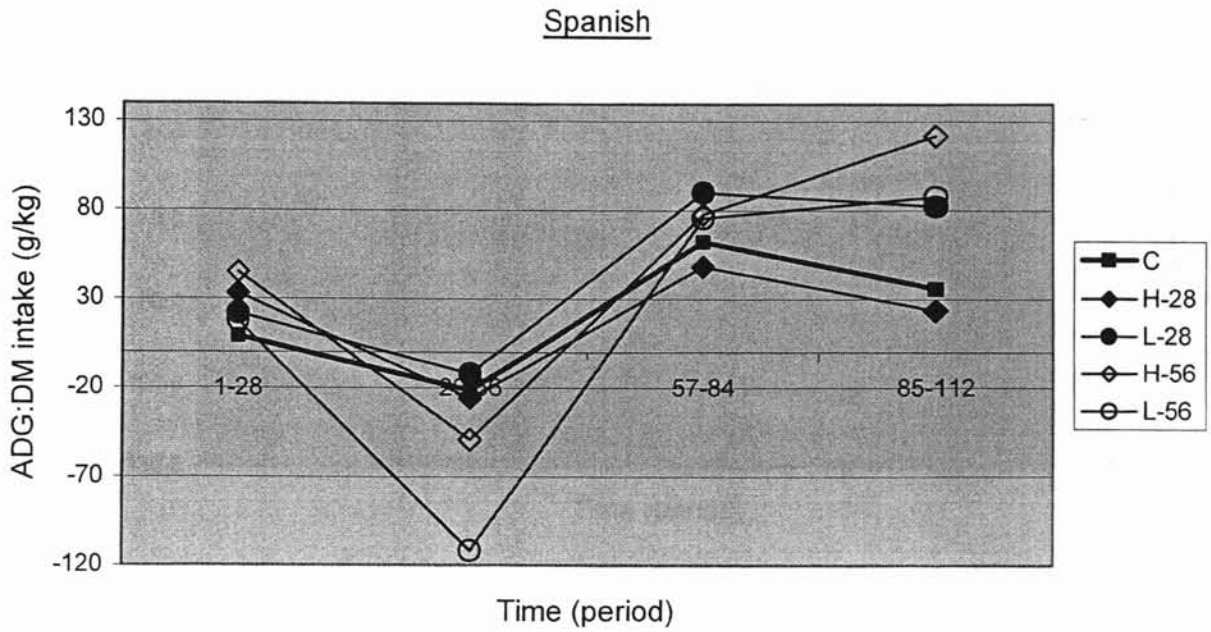


Figure 5. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on ADG:DM intake by yearling Spanish and Boer x Spanish doelings.



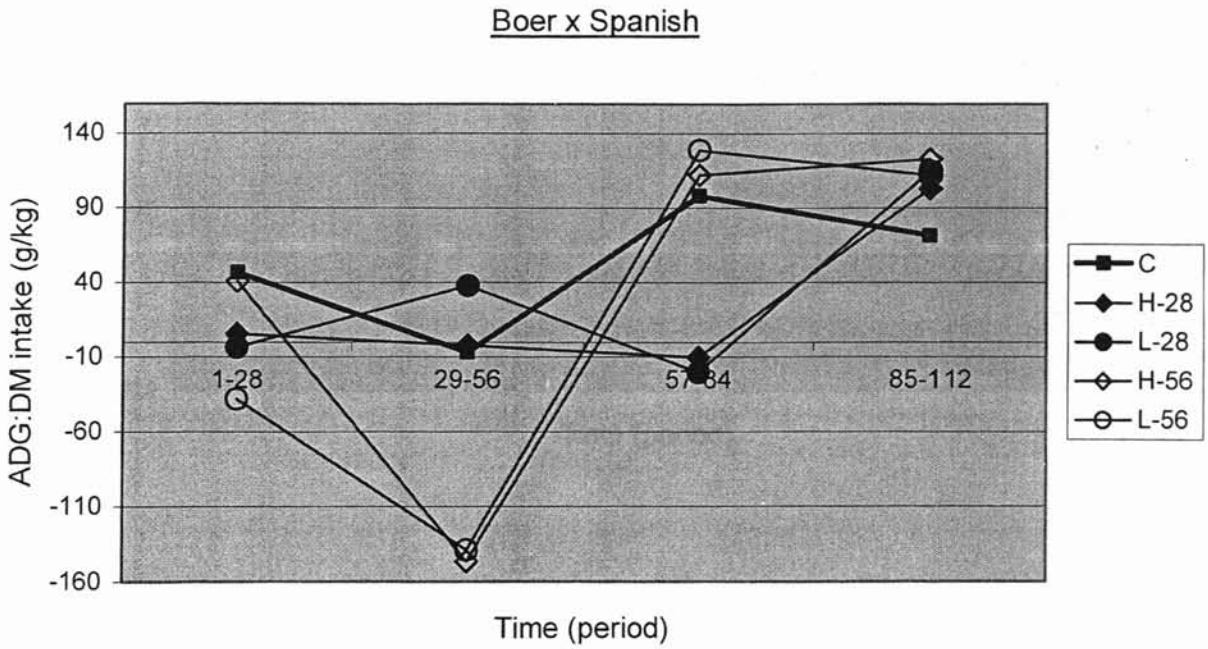
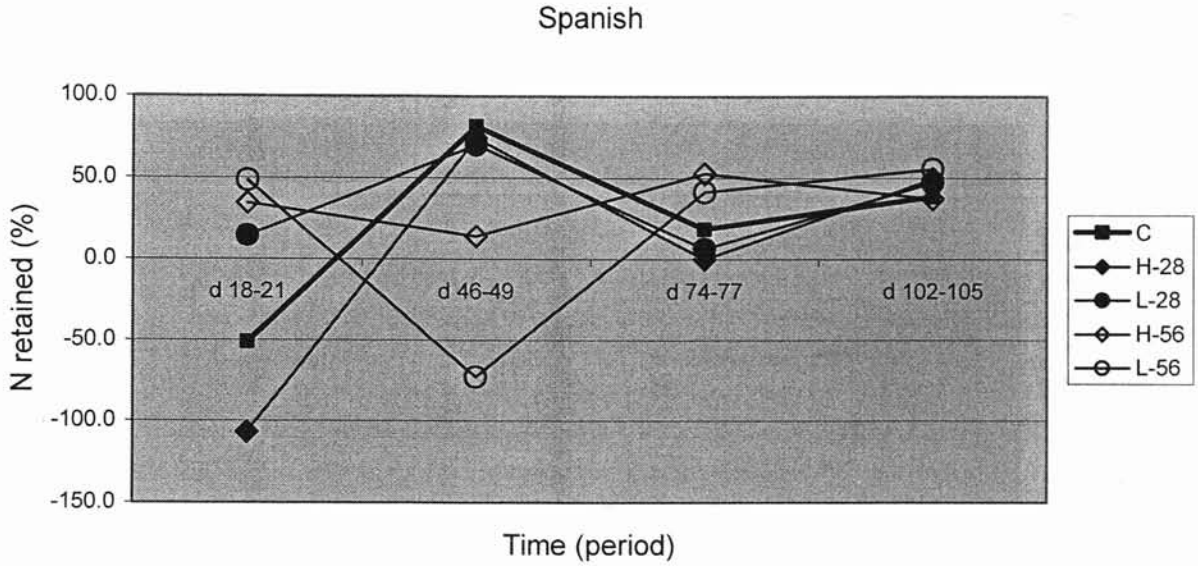


Figure 6. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on N retained as percentage of N intake by yearling Spanish and Boer x Spanish doelings.



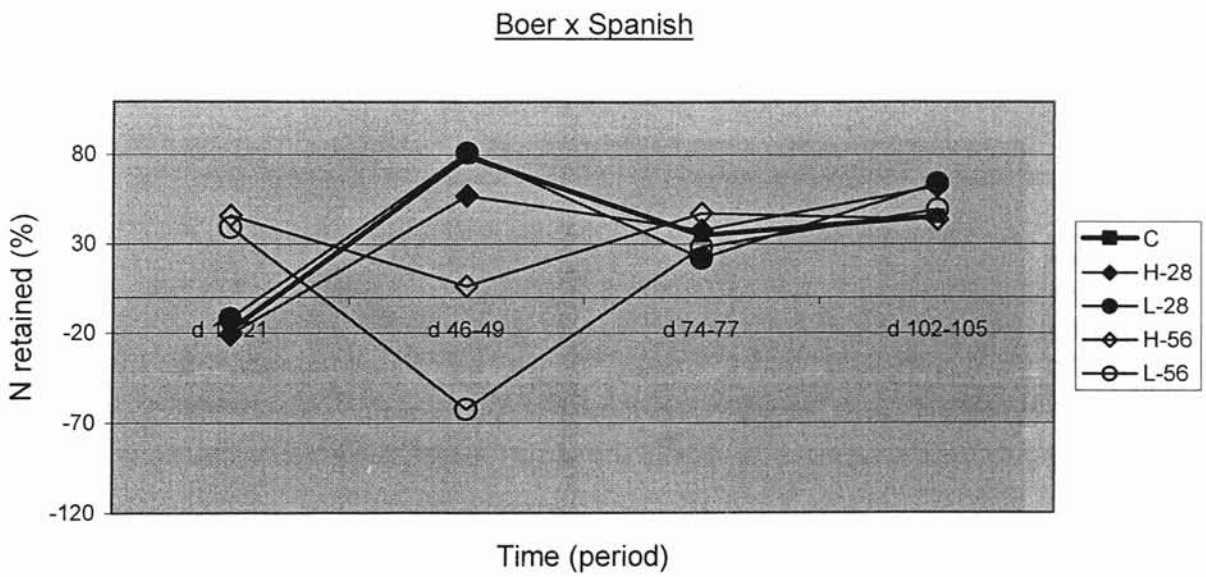


Figure 7. Effects of length of feed restriction and realimentation and level of supplementation during realimentation on blood urea N concentration in yearling Spanish and Boer x Spanish doelings.

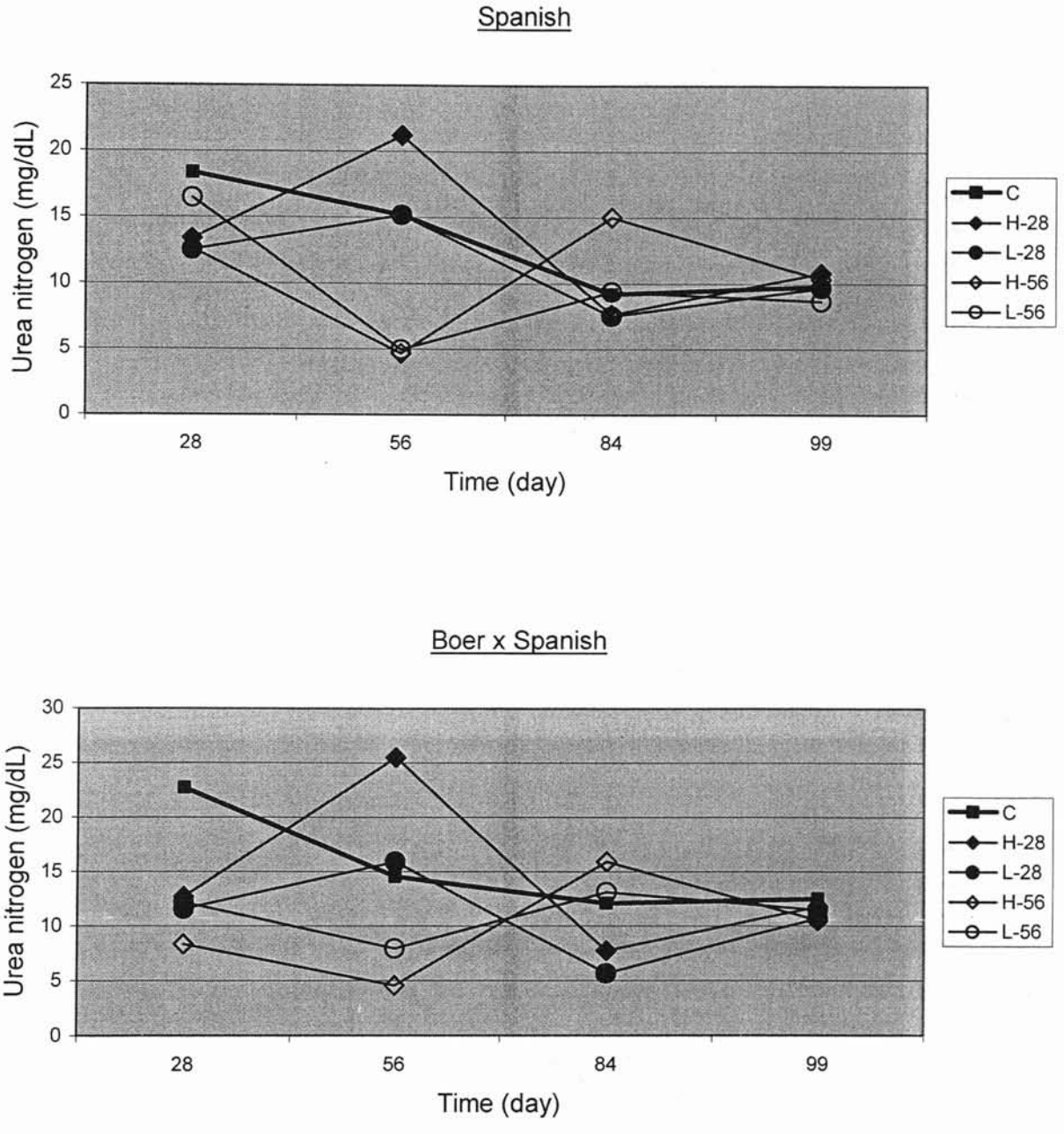
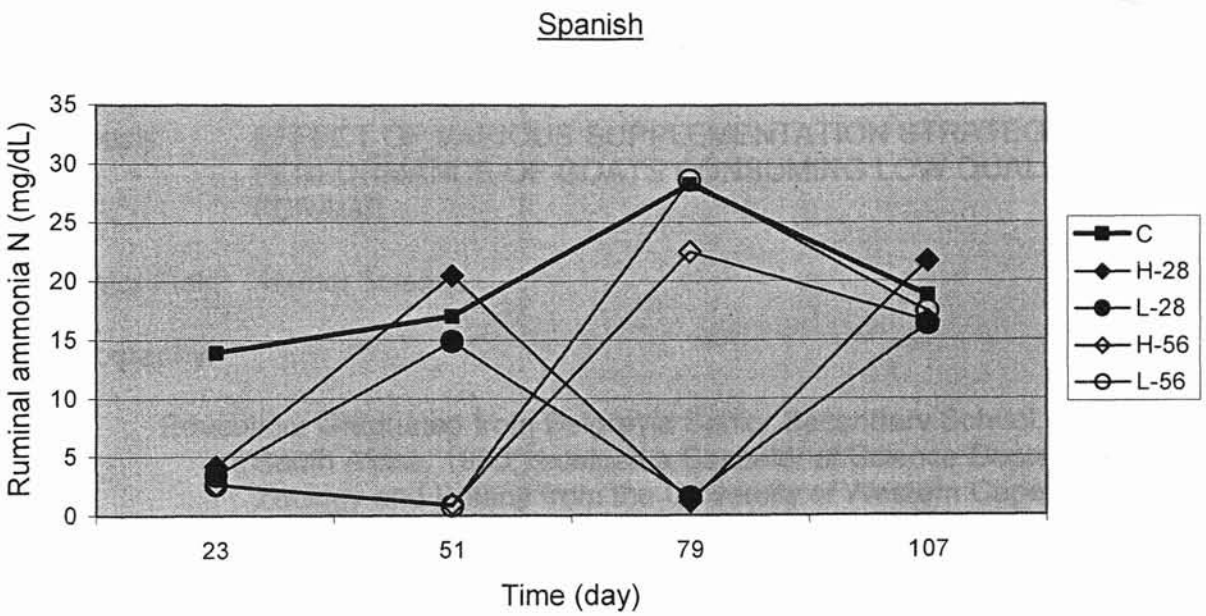
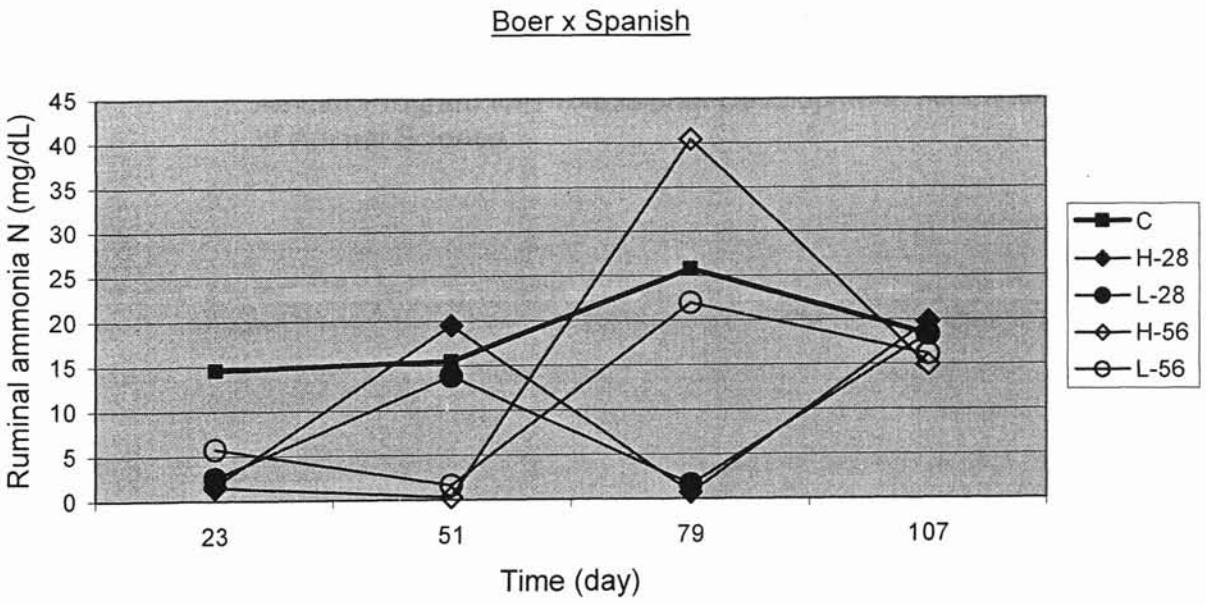


Figure 8. Effects of length of feed restriction and realimentation, and level of supplementation during realimentation on ruminal ammonia N concentration in yearling Spanish and Boer x Spanish doelings.





VITA 2

Rowena Joemat

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